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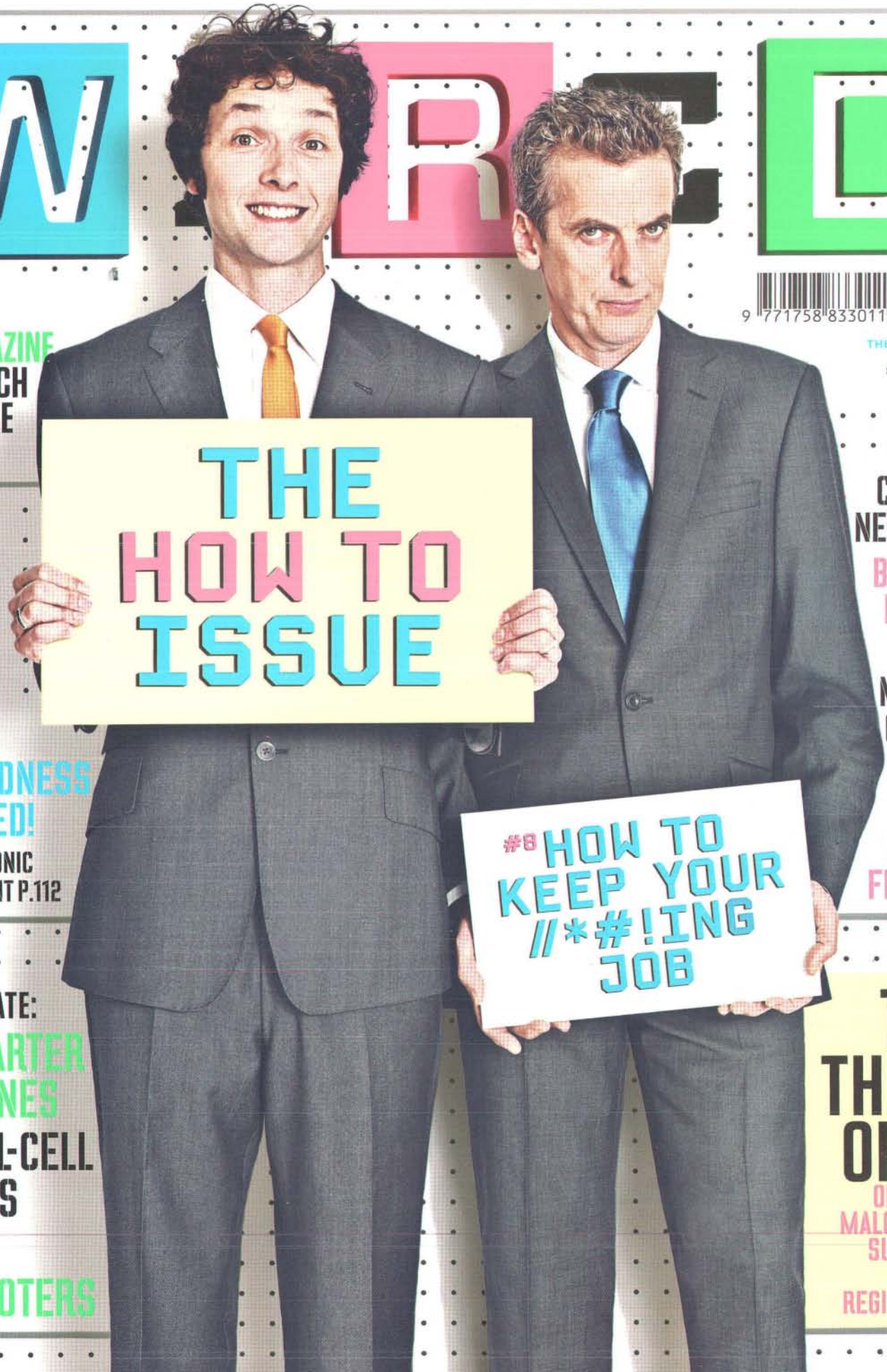

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LUS:
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CREATE NEW LIFE

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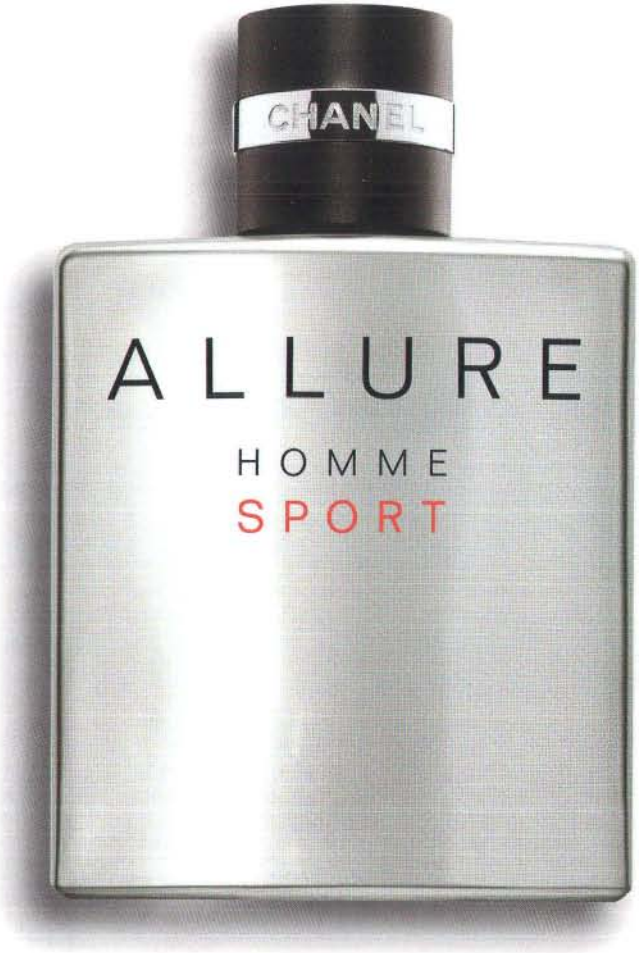
#8 HOW TO KEEP YOUR //*#!ING JOB

THE THICK OF IT'S OLLIE AND MALCOLM ON SURVIVING A NEW REGIME P.84



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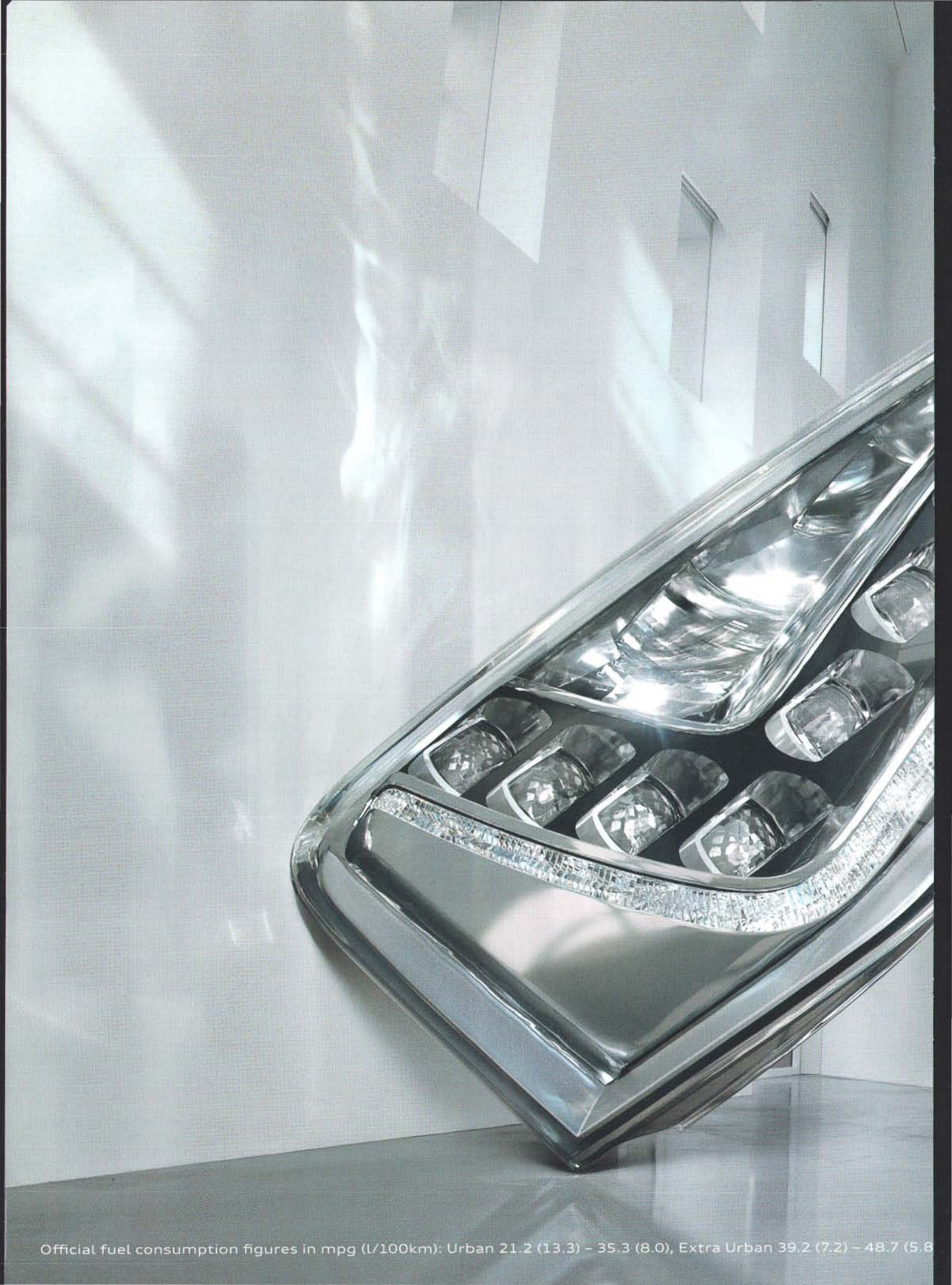

Official fuel consumption figures in mpg (l/100km): Urban 21.2 (13.3) – 35.3 (8.0), Extra Urban 39.2 (7.2) – 48.7 (5.8


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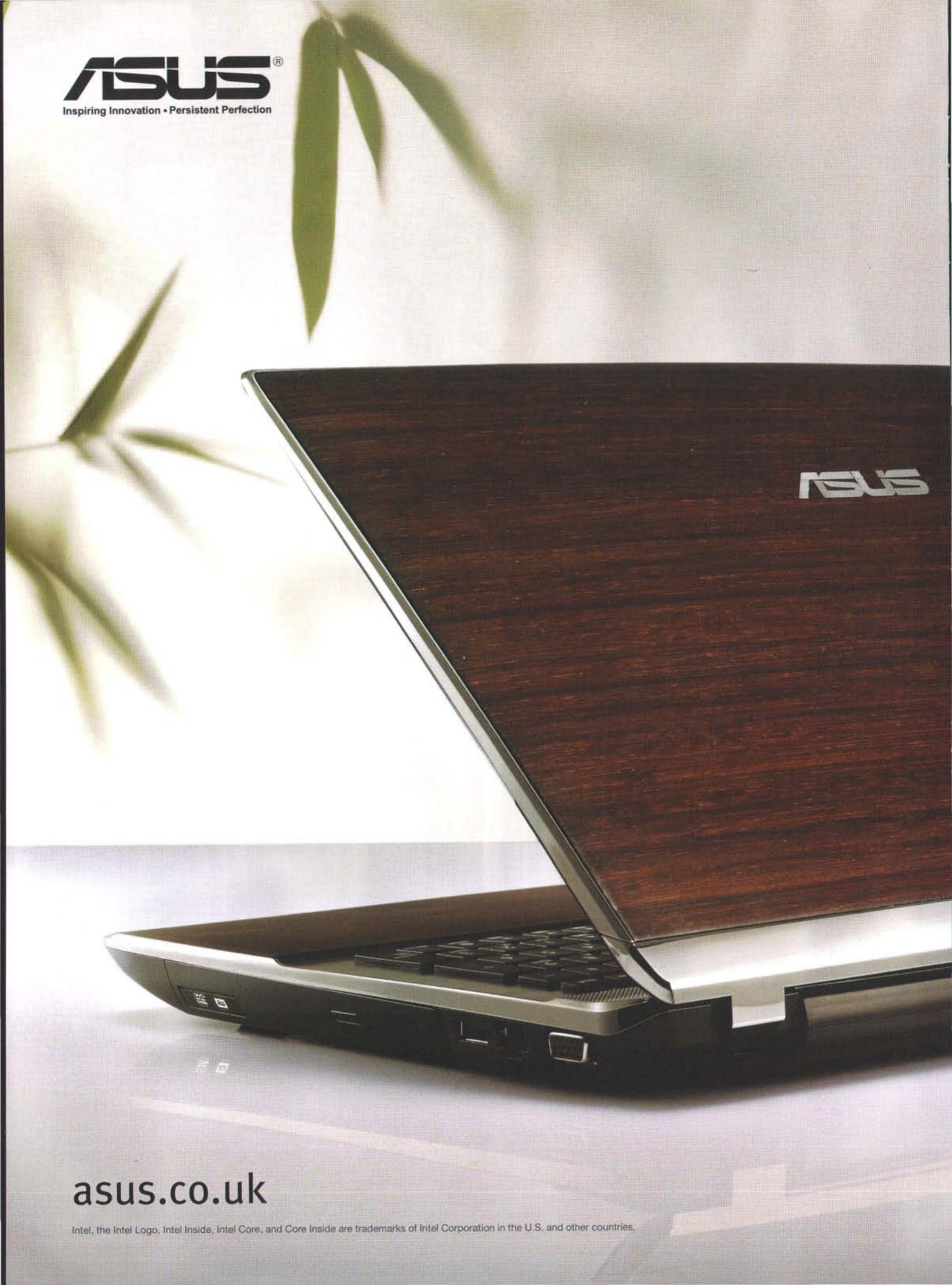
Combined 29.7 (9.5) – 42.8 (6.6). CO_2 emissions 174 – 219 g/km. All-LED headlights are optional equipment.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CONTENTS 09.10

FEATURES

Robert Greenberg has developed a prosthetic retina, giving hope to millions of blind patients

PHOTOGRAPHY: SPENCER LOWELL

CONTAINS ONLY 4 INGREDIENTS

HOPS, MALTED BARLEY, MAIZE, WATER.

STELLA ARTOIS

She is a thing of beauty

On the cover

Photography: James Day.
Set design: Andy Knight.
Stylist: Lisa Duncan

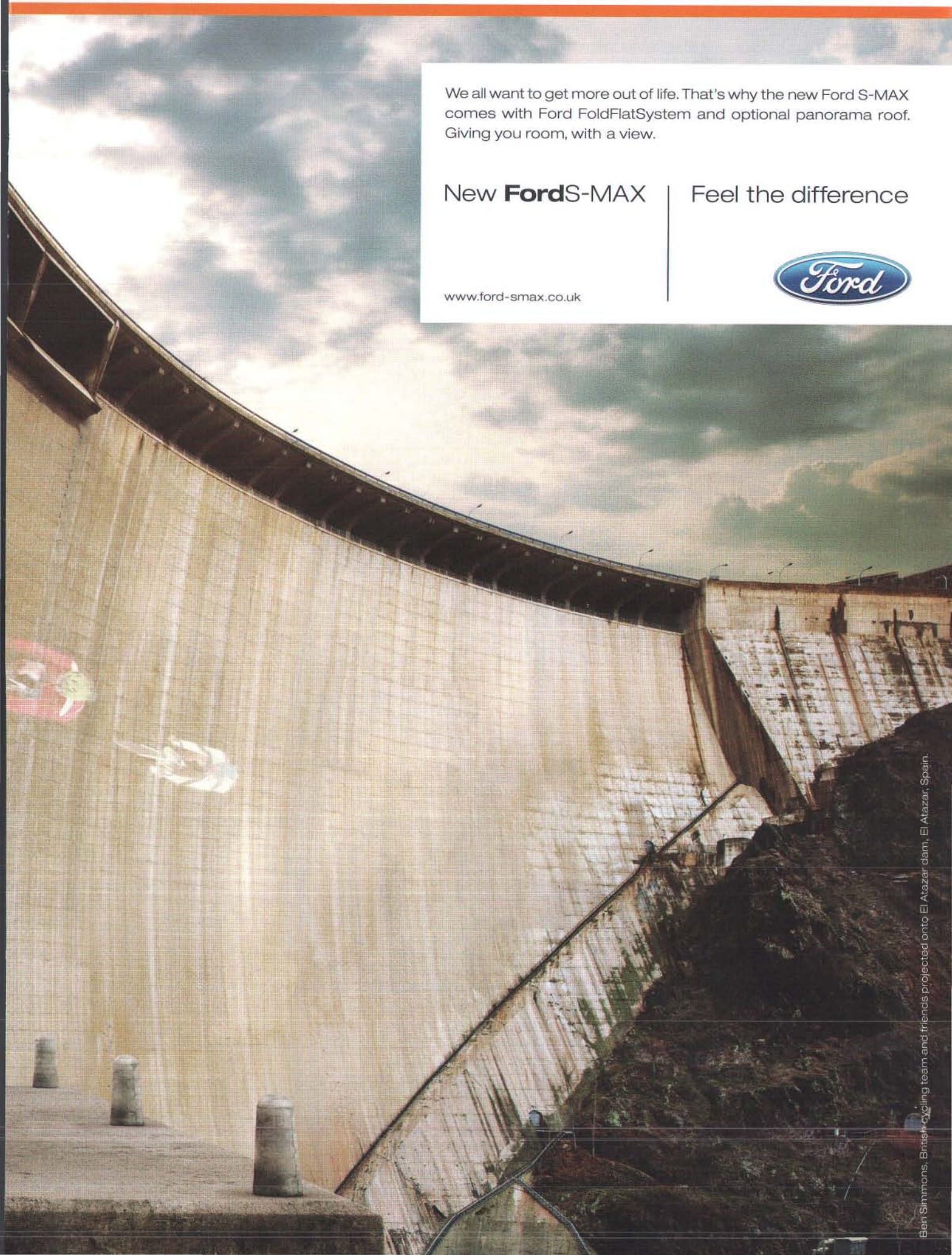
Chris Addison wears Richard James grey wool one-button suit, £895 (*www.richardjames.co.uk*), and Paul Smith London white shirt, from £89 (*paulsmith.co.uk*).

Peter Capaldi wears Paul Smith London grey suit, £719 (*paulsmith.co.uk*), and Prada white cotton shirt, £250, from Prada, 16-18 Old Bond Street, London W1, 020 7647 5000.

PHOTOGRAPHY: WILSON HENNESSY; TOM SCHIERLITZ; SHAMIL TANNA; MARTIN OEGGERLI. ILLUSTRATION: BRYAN LEE O'MALLEY

Official fuel consumption figures in mpg (l/100km) for Ford S-MAX Titanium: urban 25.0-39.2 (11.3-7.2), extra urban 44.1-57.7 (6.4-4.9), combined 34.5-49.6 (8.2-5.7).

Official CO_2 emission 152-189g/km. Model shown features optional Titanium X Pack. Panorama Roof is standard on Titanium X series and optional on Zetec and Titanium series.



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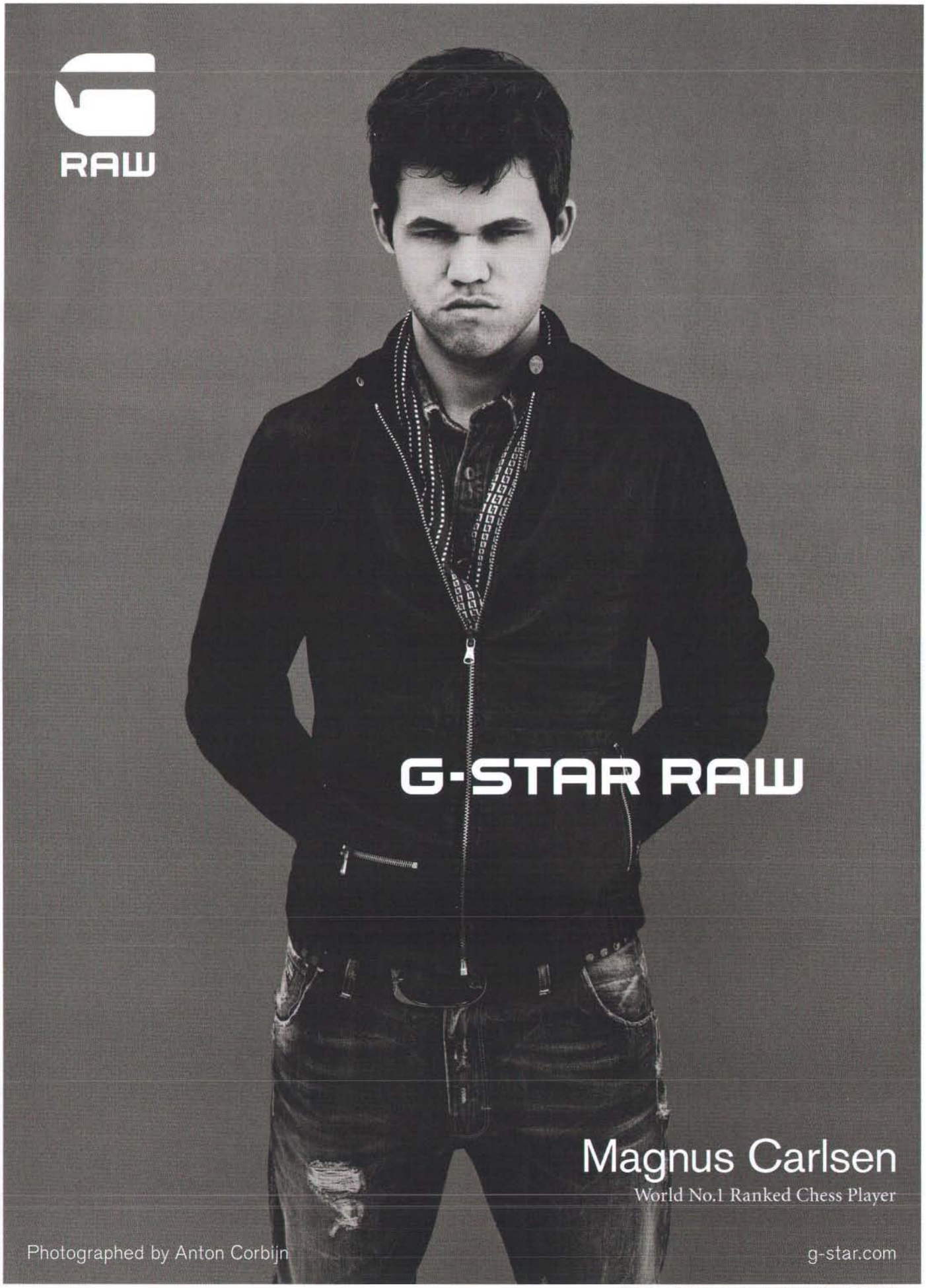


08.10
TV breaks free

Transmedia ruled the airwaves (and the internet and everything else) in our August issue. Plus: the grainy cover returned (we know you missed it)

Issue 16, as a word cloud
Although "information", "research" and "data" are all jostling for position, the prominent "Just WIRED-like" sums up the issue nicely

RANTS

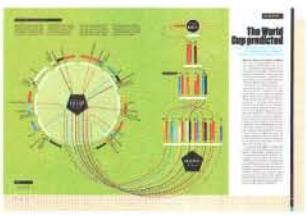
WHAT YOU THOUGHT OF OUR SIXTEENTH ISSUE

Hard playbor

In your definition of "Playbor" (Jargon watch, 07.10) you said the process "does not itself produce anything", but generates value. That's not strictly true. What it produces is a whole lot of R&D for the vendor – virtually free of charge.

"Modding" games is a prime example of playbor, in which amateur enthusiasts – for the love of the game, if you will – come up with new ideas, characters and storylines for the games they are avid fans of. In other words, the kinds of things game developers would ordinarily have to pay for.

Walé Azeez, by email



WORLD CUP TWEETS

Somehow, the football defied our data ("World Cup predicted", 06.10). We'll just ask the octopus next time...

Your #worldcup article proves that over time all data is questionable; but you did get the ENG/GER & ESP/PORT games right #final16.
@benriddell

The forces of science and progress were resoundingly trounced by a "psychic octopus" in Germany.
@gregorhunter

I blame the World Cup prediction article in @WiredUK for my dire showing in the office World Cup game. Serbia in the final? Guess again.
@Mister_Matthew

09.10

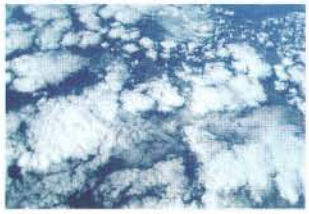
CONTACT US: RANTS@WIRED.CO.UK

Snaps from space

Together with two other 16-year-olds from Reading, we launched a high-altitude balloon ("How to photograph space", 07.10) called ALIEN-1 (ALtitude Imaging Entering Near-space) on May 2. The payload was a Canon PowerShot A560 (with CHDK), temperature sensors and a GPS receiver.

All this was controlled by an ATMega-based flight computer inside a polystyrene box. The balloon burst at an altitude of 33,158 metres, and we captured around 3,000 photos. By the way, the lowest external temperature we measured was -46°C, a bit warmer than your "minus 200°C chill";).

Simrun Basuita, Alex Breton and Daniel Richman, by email



TWEET EXTRA

Maybe it's time for a WI(RED) edition on innovative alternatives to charity.
@SILV3R

Dan Ariely says you can prolong pleasure by interrupting it (07.10). Is that like stopping during sex?
@SealTree

UNDO

We gave Christopher Nolan the credit for special effects in *Tommy*, *102 Dalmations*, *Goldeneye* and *Batman Begins* ("Who needs CGI?", 08.10). We meant Chris Corbould.

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Giulietta

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Official fuel consumption figures for the Alfa Giulietta range: Urban 26.2 – 51.4 mpg (10.8 – 5.5 l/100km); Extra Urban 48.7 – 76.4 mpg (5.8 – 3.7 l/100km); Combined 37.2 – 64.2 mpg (7.6 – 4.4 l/100km). CO_2 emissions 177 – 114 g/km.

*When compared to the Alfa 147 range.

09.10contributors

Armando Iannucci

The creator of *The Thick of It* let Malcolm Tucker and Ollie Reeder out to play in our How To special this month, where Tucker teaches us how to *really* insult someone. (WIRED takes no responsibility for what you do with this knowledge.)

Chris Finnamore

WIRED's Test editor has spent 17 issues assessing all kinds of tech – but is anything left on his wish list? "Jet packs. Sadly, there's only one available commercially, so we can't yet make a comparison." You hear that, jet-pack manufacturers?

James Day

This month's cover features the stars of *The Thick of It*, as captured by photographer James Day. "Chris [Addison] and Peter [Capaldi] were great," says Day. "I just let them do their thing." So did he learn any new insults? "No, they were charming."

Chris Anderson

The editor-in-chief of WIRED US has a secret life – he builds UAVs, and can show you how to make one. "I've lost three planes, all due to human error," he says. "But one is still going after three ocean crashes. It's taped together."

Spencer Lowell

An LA-based photographer, Lowell visited a laboratory creating a prosthesis that returns limited sight to the blind. "If I lost my sight, I'd get a retinal implant," says Lowell. "I like that blindness may not be permanent."

Robert Cialdini & Steve Martin

The authors of *Yes! 50 Secrets from the Science of Persuasion* show our new government how to usefully modify UK citizens' behaviour. It's not brainwashing – just smart psychology. See more tricks at *scienceofyes.com*

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> 2 WIRED PHOTOS

Beautiful photo-stories on everything from the latest images captured by the world's space telescopes, to how hydrogen-powered cars are refuelled. And if you enjoy failed car-safety experiments, don't miss WIRED's amazing video of when a crash test goes very wrong.

> 3 WIRED ARCHIVE

Missed the last issue? No problem. We aim to post every feature and article from each magazine by the end of the month that it went on sale – which means you can read articles from every issue of WIRED UK in our comprehensive online archive.

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BEST BUY which? www.which.co.uk Digital Cameras June 2010

Photograph taken by David Eustace using the Lumix GF1 for Professional Photographer Magazine. To see more of his work visit davideustace.com

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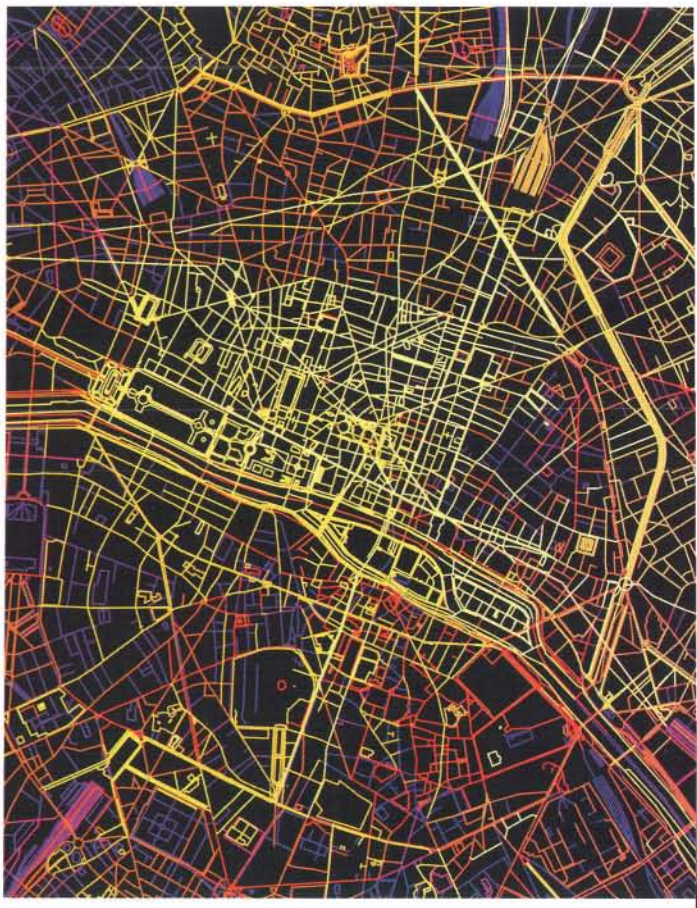
FROM THE EDITOR

WIRED



Paris, the city of lights, illuminated by crowdsourced data (see p107)

In late June, a smart coder named Matthew Somerville took an open data feed from Transport for London and built a live Google map showing Underground trains' movements in real time. The map went viral, and within days had contributed to what TfL said were ten million hits that risked crashing its servers. Somerville had proved how popular and valuable raw data can be once visualisations have turned it into – well, into information.

This month James Silver reports on the real benefits of open data – from crowdsourced maps that saved lives in Haiti, to charts of live aircraft movements that informed my own decisions when ash clouds trapped me in Moscow. Give developers access to live data feeds, and they will build beautiful, useful and unforeseen tools that benefit us all. So all credit to bodies such as the London Datastore, which, with the mayor's backing, are not merely releasing the Greater London Authority's data for the benefit of the capital's citizens, but also putting pressure on other public bodies to join the revolution.

Still, some dinosaurs flatly refuse to serve the public good. Chief among them is National Rail Enquiries, owned by the Association of Train Operating Companies, which continues to reject calls to open up its feeds – despite collecting huge taxpayer subsidies. When I asked why, a press officer said "it just isn't practical to make [services] entirely open to developers" as data was constantly being updated and the system would face "extra strain". Nonsense: it's simply an excuse to maximise revenues by charging for data that should be freely available. In response, our new "open" prime minister should threaten to withdraw public subsidy. We're going to campaign more on this. Sign up at *editorial@wired.co.uk*.

■ Following our British Society of Magazine Editors "Launch of the Year" award, I'm delighted that art director Andrew Diprose has won Designer of the Year at the Periodical Publishers Association awards, the big prize in consumer magazines. Judges cited WIRED as "one of the most talked about and eagerly anticipated magazines" whose "terrific content, typography and attention to detail have made WIRED a winner". Design thinking at work!

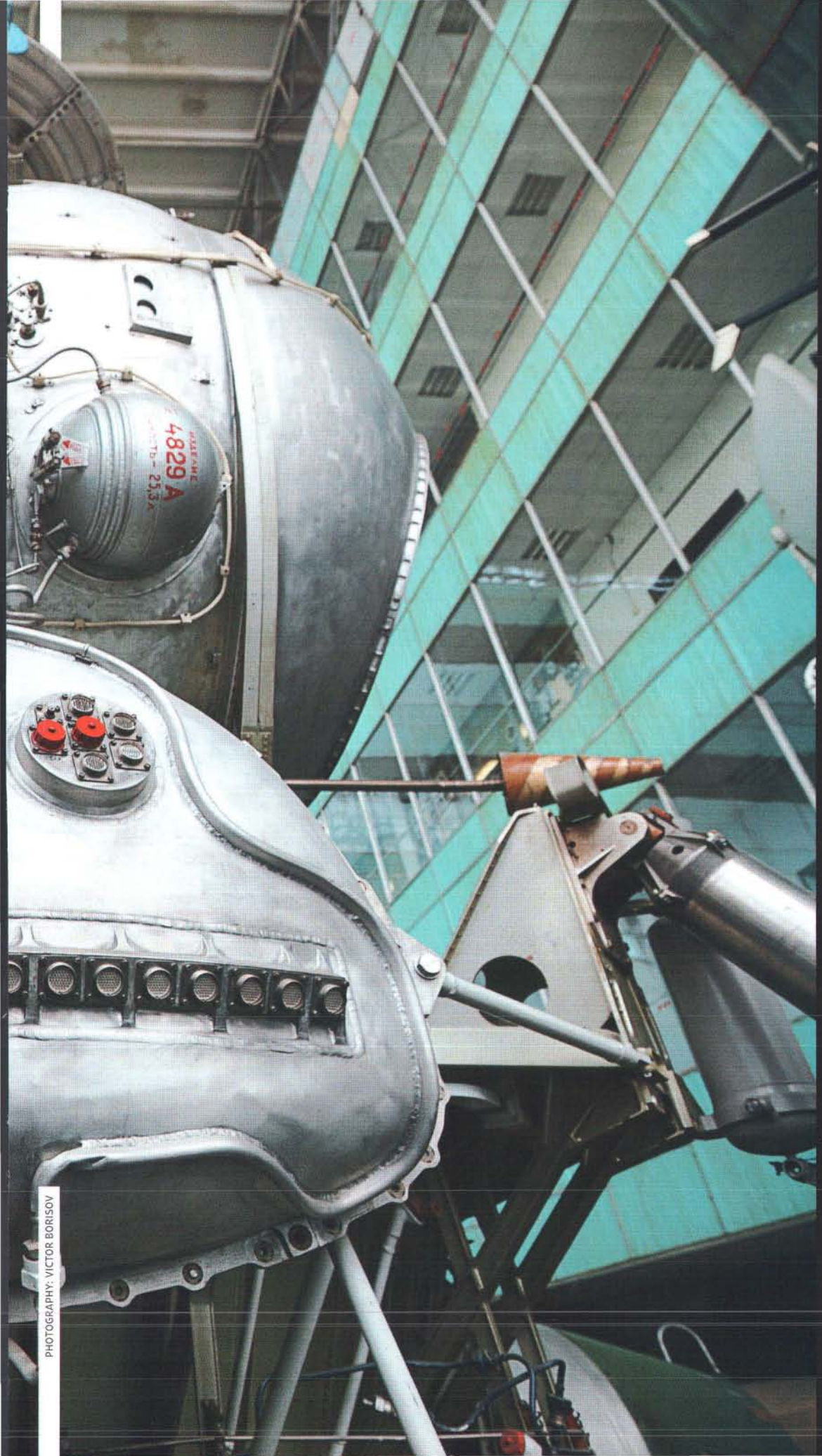
UK and French airspace, as seen by Flightradar24.com (see p110)

David Rowan, Editor

start

NEWS AND OBSESSIONS 09.10

EDITED BY JOÃO MEDEIROS



PHOTOGRAPHY: VICTOR BORISOV

A face of the space race

Grinning forlornly like the Cheshire Cat, a Soviet mock-up lunar module stares down the decades in the Moscow State Aviation Institute's research hangar. Photographer and blogger Victor Borisov gained access to it and dozens of other rarely seen space-race-era artefacts kept there. The archive includes student-built satellites, full-scale replicas and engineering models of Venus probes and an array of landers from the 60s and 70s.

This lander was used for testing during Soviet efforts to land a single cosmonaut on the Moon in the 60s, says James Oberg, a former Nasa engineer and author of *Red Star in Orbit*. The programme was scrapped after Apollo got there first. Although Borisov's subjects date from a more analogue era, they recall an astoundingly innovative time. "It was a political race that propelled this," he says. "Now it's too expensive."

Today, students at this premier engineering academy use the model Moon lander for study, but the institute still tries to set the pace in space-module design. It is currently workong with clients such as Russia's SP Korolev Rocket and Space Corporation Energia on the International Space Station. **Michael Dumiak**

Shopping with the tag lady

Ulla-Maaria Engeström's start-up is tagging the world's photos – to help you find (and buy) products online

"The things that have the most personality – art, craft and vintage objects – can't be easily recommended, because they can't be easily identified," says Ulla-Maaria Engeström (*above*). With her start-up, Thinglink, the Helsinki-based design consultant plans to bring visibility to this "invisible tail" of hard-to-find objects.

Users can embed Thinglink's photo-tagging tool on their websites and set up info-packed hot-spots on their images. "People love to share images – and data," explains Engeström, 36.

Thinglink's staff include her husband Jyri and Petteri Koponen, who cocreated Jaiku, an early microblogging service bought by Google in 2007. CTO Janne Jalkanen is a former rocket scientist and head of early technology validation at Nokia.

Engeström, who was the former director of the Institute for Design Research and is currently working on a PhD in collaborative design, hopes to connect web users with quality and sustainable design through Thinglink. "We can make it easier – and cooler – to find interesting alternatives to mass-produced goods." *thinglink.com*

Daniel Nye Griffiths

PROFILE

Name: Ulla-Maaria Engeström
Job: CEO of Thinglink
Location: Helsinki, Finland

This piece took 10,000 hours to write

A bunch of books claim you don't need talent to win – just a decade of practice

What's the secret of high achievement? It's not talent or natural genius, according to a wave of new books on the "science of success" – the key is practice. All the books lean heavily on the work of psychologist Anders Ericsson, who found that what distinguished world-class violinists from mediocre tunesmiths wasn't that they were "naturals" – it was that by their twenties they'd practised for 10,000 hours. So forget your innate intelligence or parental wealth: rely on WIRED's guide to winning. **DR**

The Genius in All of Us

Why Everything You've Been Told About Genetics, Talent and Intelligence is Wrong
By David Shenk (Icon Books)

Key message: "Talent is not a thing; it's a process. The whole concept of genetic giftedness turns out to be wildly off the mark. Our abilities are not set in genetic stone. They are soft and sculptable."
How to succeed: Sorry – it's too late for you. Still, lifestyle changes now can alter the genes that your unborn children will inherit; this can boost their own kids.
Homage to Malcolm Gladwell: Cites Gladwell's explanation of why Kenya produces so many top runners: by typically running "70 miles a week" to and from school.
Passing reference to Tiger Woods: Yes
Notable footnote: "To be clear, 'Great Jewish basketball players' is not a joke."

Bounce

Mozart, Federer, Picasso, Beckham and the Science of Success
By Matthew Syed (Harper)

Key message: "We like to think that sport is a meritocracy – where achievement is driven by ability and hard work – but it is nothing of the sort... The talent theory of expertise is not merely flawed in theory; it is insidious in practice, robbing individuals and institutions of the motivation to change."
How to succeed: "From art to science and from board games to tennis... a minimum of ten years is required to reach world-class status."
Homage to Malcolm Gladwell: Quotes from his "marvellous" *Outliers* (qv) – also citing Gladwell on pp9, 16, 17, 18, 140, 143.
Tiger Woods reference: Yes
Notable footnote: The author was Britain's number-one table-tennis player from 1995 to 2003.

Talent is Overrated

What Really Separates World-Class Performers from Everybody Else
By Geoff Colvin (Nicholas Brealey)

Key message: "The differences between expert performers and normal adults reflect a life-long period of deliberate effort to improve performance in a specific domain."
How to succeed: You don't need talent. Instead, apply "deliberate practice" in your personal life and corporation. That means you need "a mental model" and a feedback strategy.
Homage to Malcolm Gladwell: In *Blink*, Gladwell "does not venture to explain" an uncanny skill he observes in a subject, leaving it "as an intriguing mystery". So, not *really* a homage.
Tiger woods reference: Yes
Notable footnote: Nobel Prizewinners are getting older.

Outliers

The Story of Success
By Malcolm Gladwell (Allen Lane)

Key message: Choose your birthday carefully. Be born around 1955 if you want to be a software billionaire (Steve Jobs, Eric Schmidt, Bill Gates), or as soon as possible after January 1 to be a Canadian hockey champ.
How to succeed: "Researchers have settled on what they believe is the magic number for true expertise: 10,000 hours. This is true even of people we think of as prodigies."
Homage to Malcolm Gladwell: Cites Gladwell's mother, Gladwell's father, Gladwell's grandmother, Gladwell's great-great-great-grandmother, and Gladwell's own earlier book *The Tipping Point*.
Tiger Woods reference: No
Notable footnote: On calculating the probability that The Beatles had met the 10,000-hours rule by their great year of 1964.

Conclusion: Practise for 10,000 hours, do what Tiger Woods does, and try to give your children Malcolm Gladwell's genes.

Each month WIRED's chemist Dr John Emsley, author of nine books and 110 research papers, deconstructs an everyday product. This month: Ribena Really Light drink

what's inside>
Ribena Really Light Blackcurrant

A sip of hair straightener

Banish curly hair, clean your toilet and quench your thirst – all while watching your waistline

Ingredients
>Water
>Blackcurrant juice from concentrate (seven per cent)
>Malic acid
>Acidity regulators (calcium hydroxide, calcium carbonate)
>Vitamin C
>Sweeteners (aspartame, acesulfame K)
>Citric acid
>Stabiliser (xanthan gum)
>Flavouring
>Colour (anthrocyanins)

Malic acid (aka E296)
This acid ($C_4H_6O_5$) converts into sweet-tasting molecules. Nature produces only left-hand forms but that produced by the chemical industry contains left- and right-hand forms.

Calcium hydroxide (aka slaked lime, $Ca(OH)_2$, E526)
This is added to keep the pH of the drink (which is slightly acid) at a constant level. This chemical is also used to straighten curly hair.

Calcium carbonate (aka limestone, $CaCO_3$, E170)
This forms limescale when hard water is heated. It is also what indigestion tablets are made of. It acts to stabilise the pH of the drink.

Artificial sweeteners aspartame and acesulfame K
Intense sweeteners such as aspartame consist of two amino acids; acesulfame is a sulphur nitrogen molecule which is made soluble as it is a potassium salt (hence the K symbol).

Vitamin C (aka ascorbic acid, E300)
The RDA of vitamin C is 60mg and blackcurrants contain this vitamin – but the amount coming from the seven per cent of fruits in this drink needs to be boosted by the addition of this man-made vitamin C.

Citric acid (aka E330)
This is a natural acid produced by many fruits. It is regarded as a "green" acid because it is produced in nature, although most is made synthetically. It is used in eco-friendly toilet-bowl cleaners to remove limescale.

Anthocyanins (aka E163)
These are natural pigments that can be red, blue or purple – they give colour to blackcurrants. The anthocyanins are reputed to protect against cancer because they absorb damaging UV rays.

Xanthan gum (aka E415)
This carbohydrate is used as a thickening agent, but it also preserves components in food, which is what it does for the blackcurrant-juice concentrate. It's made by fermenting corn starch.

> START

PHOTOGRAPHY: MATHEW SHAVE

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SAMSUNG

TURN ON TOMORROW

Jargon watch

Mujicomp, n.
The notion that ubiquitous computing, or "ubicomp", needs to reproduce the design approach of Japanese retailer Muji to break into the mainstream. According to Matt Jones, design director at BERG, most existing ubicomp products are still too niche and techy. Mujicomp implies the delivery of tasteful, simple, practical and affordable products.

Narcotecture, n.
Ostentatious residential manifestations of the drug trade in Afghanistan. Clashing with the mud-brick residences of poorer citizens, these neo-narco palaces are adorned with sparkly mirrors, Corinthian columns and other cheesy signifiers of wealth. However, construction is said to be shoddy and many of these houses may already be cracking.

Tabnapping, n.
A new phishing technique that dupes users into giving up passwords by secretly changing already-open browser tabs. As if "kidnapping a tab", the attackers replace open pages with a Gmail login look-alike. The user will most likely think they left a Gmail tab open and re-log in. The login information is then sent back to the attacker.
Estelle Ricoux

Private divers

Graham Hawkes wants to make deep-sea exploration available to all – by building you a personal submarine

Oceans cover 70 per cent of Earth's surface but remain largely unexplored. So engineer Graham Hawkes created "underwater aircraft" – winged submarines that fly through the water. Designed and built at Hawkes Ocean Technologies in San Francisco, his Deep Flight submersibles are lighter than water, so they use short wings and electric thrusters. "The ocean begs to be explored, but we couldn't do it properly with ballast subs," says Hawkes. "My subs give the experience of flying with marine life." The current model, the Merlin, can be yours for around £440,000. *deepflight.com* **Daniel Cossins**

HAWKES'S UNDERWATER FLYING MACHINES

Deep Flight Challenger (2005-2008)
Hawkes built this to take adventurer Steve Fossett down to the Marianas Trench, the deepest point in the ocean at 11,000 metres. It was to descend 100 metres per second. Fossett died in 2007, so the Challenger never reached the bottom of the sea.

Deep Flight Super Falcon (2009)
This sleek £1.5-million machine (*right*) can reach depths of up to 300 metres, where the pilot and one passenger can cruise at up to five knots for six hours. It weighs in at 1,820kg, less than half that of conventional two-seater subs.

Deep Flight Merlin (2010)
The Merlin is designed to offer the experience of underwater "flight" at depths of 40 metres and above. The open-cockpit design means that the pilot and two passengers have 360-degree views. And yes, Richard Branson already owns one.

Deep Flight II
Applying what he learned on the Challenger project, Hawkes has designed (but not yet built) a lightweight deep-sea sub. It too will be capable of reaching 11,000 metres, where its LED lamps will allow the pilot to peer into the inky-black depths.

« Most claps in 30 seconds while standing on one leg: 136... »

PHOTOGRAPHY: MISHA GRAVENOR; MATTHEW TAYLOR


The Super Falcon can pitch and roll 180 degrees, controlled by a cockpit joystick

DAN ARIELY

'It's not that I think bankers plot crimes for a living, but...'

There is a certain perverse pleasure in contemplating the perfect crime. You can apply your ingenuity to the hypothetical issues of choosing a target, evading surveillance and law enforcement, dealing with contingencies and covering your tracks afterwards. You can prove to yourself, whenever you wish, what an accomplished criminal mastermind you would be, if you so chose.

The perfect crime is usually a bank robbery in which the criminals cleverly bypass all security systems using neat gadgets and knowledge they've acquired over weeks of casing the joint. This seems to be an ideal crime because we can applaud the criminals' cunning, intelligence and resourcefulness, but it's not *quite* perfect. After all, contingencies by definition depend on chance and therefore can't ever be perfectly thought out. Even if the chances of being caught are close to zero, do we really want to call this a perfect crime? The authorities are likely to take it very seriously and respond accordingly with harsh punishment. In this light, the 0.001 per cent chance of getting caught might not seem like a lot; but if you take into account the severity of the punishment, such crimes suddenly seem much less perfect.

To my mind, the perfect crime is one that not only yields more money, but is one where, if you did get caught, no one would care and the punishment would be negligible.

So, armed with this new knowledge, how would you go about it?

Firstly, the crime would need to be obscure and confusing, making it difficult to detect. Stealing jewellery is too straightforward. Second, the crime should involve many people engaging in the same type of crime so that no one can point a finger at you. This is why looting, though easy to detect, is much more difficult to get a handle on than a single robbery. Third, your crime will need to fall under the shady umbrella of plausible deniability so that, if you get caught, you can always say you didn't know it was wrong in the first place. With this kind of defence, even if the public cares, the legal system may let you off lightly. Moreover, plausible deniability allows you to apologise in the aftermath and ask forgiveness for your "mistake".

If you really want to go all out, select something you can spin in a positive light and maybe even create an ideology around. This way you can then explain how you're actually on the side of progress. Say, for instance, you're "providing liquidity" and "lubricating the market" and thereby helping the economy – even if it happens to be by taking people's money. You can also resort to opaque and promising-sounding language to make your case – you're "restoring equilibrium", "eliminating arbitrage" and creating "opportunity" and "efficiency" across the board.

Something to avoid, on the other hand, is anything involving an identifiable victim with whom people can sympathise and feel sorry for. Don't rob one little old lady blind, or any one individual for that matter. Crimes such as burglaries are the least ideal crime: they're simple, detectable, perpetrated by a single individual or just a few people. They create an obvious victim and can't be cloaked in rhetoric. Instead, what you should aim for is to steal a little bit of money from as many people as possible – little, old or otherwise; it doesn't matter, as long as you don't reverse the fortune of any one person. After all, when lots of individuals suffer just a bit, people won't mind as much.

So, what is the ideal crime? Which activity is difficult to detect, involves many people, has plausible deniability, can be supported by an ideology and affects many individuals just a bit? Yes, I think you know the answer, and it does involve banks...

Seriously, what we have here is a problem with our priorities. We have tremendous regulations for what is legal and illegal in the domain of possessions and blue-collar crime. But what about regulations in banking? It is not that I think that bankers plot crimes for a living; but I do think they are faced with tremendous conflicts of interest, and as a consequence they see reality in a way that fits their own wallets and not their clients'. The recent turmoil in the market is just a symptom of this conflict-of-interest problem. And unless we remove this from the banking system, we are going to be part of a long stream of perfect crimes.

ILLUSTRATION: ANDREW WHEATLEY

> START

MICROBIOGRAPHY

Dan Ariely is the James B Duke professor of behavioural economics at Duke University, North Carolina, and the author of *The Upside of Irrationality* (Harper Collins)

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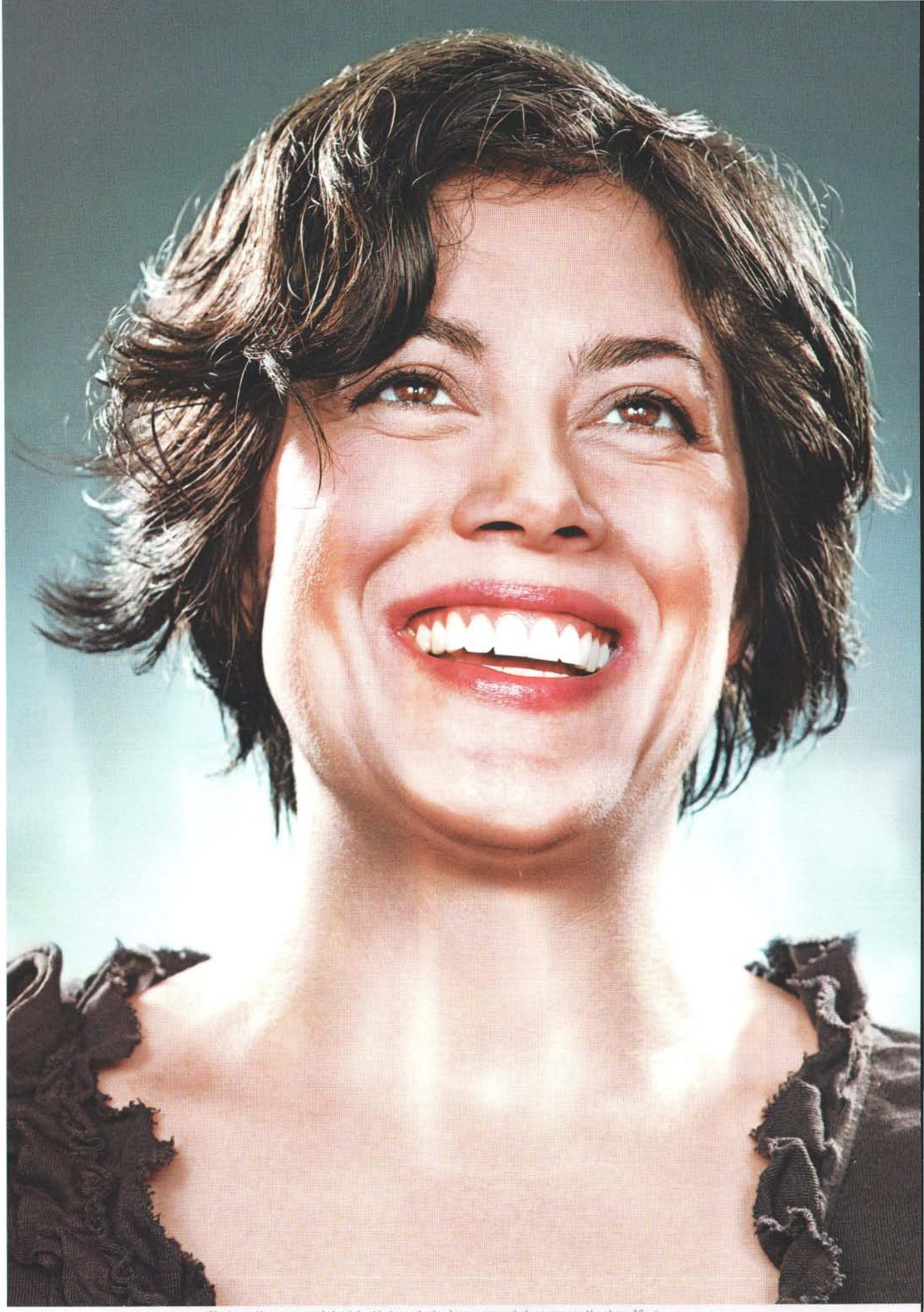


< Most questions answered about *Lost* in two minutes by someone who's never seen the show: 18... >

She has a hunch about your taste

Caterina Fake's Hunch is at the forefront of social search engines – logging your likes and dislikes, then spinning the data into smart recommendations

She's best known as cofounder of Flickr, the photo-sharing site whose members have uploaded more than four billion images – and which Yahoo bought for a reported $35 million back in 2005. But now Caterina Fake (*left*) is back, as chief product officer of a fast-growing social-sharing start-up called Hunch. Its bold aim: to "personalise the internet" by learning what you like and dislike, how you think, and what products people similar to you rate – so that it can build "a taste profile mapping your unique tastes and preferences", and then make product recommendations.

Fake launched the site last June with cofounder Chris Dixon, who was excited by a process called collaborative filtering. Amazon uses collaborative filtering to suggest what other customers-who-bought-this liked, as does Netflix, which mines user ratings to recommend movies to rent. "I thought if you could create a search engine that could learn from the input of users, you would have the magic recipe," says Fake, 42, who grew up in New Jersey the daughter of a Filipina immigrant mother and an American insurance-exec father. She developed Hunch's "About You" queries, which ask about your likes and dislikes – and then ask some more. The average user has answered 152 queries, producing a total of 55 million preferences. And, she says, all that data proves highly predictive: "It turns out that whether or not you believe in angels is very predictive of whether you are going to enjoy a show involving Oprah [Winfrey]." Ultimately, the goal isn't just helping people shop – it's getting its users to offer up a huge amount of unique psychographic data.

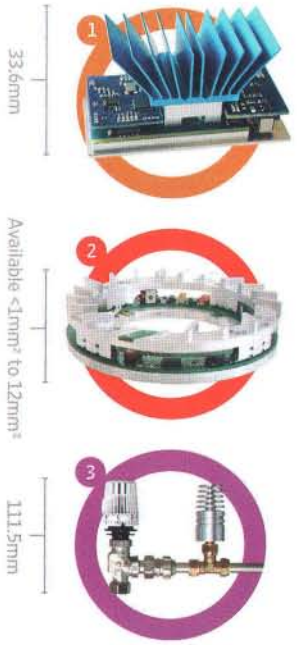
Investors see commercial opportunities in product recommendation – Khosla Ventures led a $12 million investment round in March. After all, it drives spending. As Fake's own profile reveals, "On Hunch's recommendation I've bought a laptop bag, a digital camera, started reading Thomas Kuhn as well as various blogs, and started tying my scarves differently. And have made a bunch of contributions which I hope will influence people to start listening to Kyuss, reading *Cabinet*, and eating Lesley Stowe's Raincoast Crisps."

What, then, does Hunch know about you? If you believe in UFOs, you're more likely to prefer drinking Pepsi to Coke. If you're an only child, you're predicted to be more of a cat person. And what of WIRED readers? Chances are you'll be attracted to redheads... *hunch.com* **OB**

PROFILE

Name: **Caterina Fake**
Job: **Chief product officer, Hunch**
Location: **San Francisco**

PHOTOGRAPHY: JILL GREENBERG



MINIATURE POWER STATIONS

Millimetre-scale energy-scavenging devices developed by German firm Micropelt are heralding a new breed of wireless sensors that can operate without batteries. Attached to a hot surface, the devices can generate 10mW of power from a 65°C temperature gradient, equivalent to the output of 30 AA batteries. Oil giant Shell field-tested the devices at its Den Helder factory in northern Holland; the company aims to use energy-scavenging devices in areas considered too costly or dangerous to maintain a battery-powered sensor.
Frank Swain

1. Hot-surface thermo-harvester (t-h)
2. Spinning-shaft t-h
3. Pipe t-h

RUSSELL M DAVIES

'What could I be doing with words that I can't do anywhere else?'

Two words? Or a fragment like this? Maybe the natural unit of writing is a proper sentence containing a single thought. Twitter has shown that 140 characters will do for ideas. And it's long enough to get you fired. This column will be 700-or-so words; the Gettysburg Address managed with just 256. *On The Origin Of Species* is 152,000. These sizes seem right. Columns, speeches, books – we have a sense of how long they should be.

But this apparently natural order of things is being disrupted. When the publishing of words is unconstrained by economics, new forms emerge, influenced by previous conventions but also shaped by technology and community – rather than deadlines or the need to fit between ads. So you get the different styles of Facebook, Twitter or IRC. And you find the right way to talk in all the little interstitial places, such as the chat channel on *Words With Friends*.

The conventions of print feel natural and obvious because we've grown up with them, been trained in them, gone to school to learn them. But column size, article length etc are as much to do with the physics and economics of production as they are with the human attributes of attention and comprehension. What size page can you hold in your hand? How much paper can we squeeze through a machine? How big are the shelves at Waterstone's? How many ads do we need to fit in? How much subbing can a sub sub in a day?

We've always assumed that the web atomises content; breaks it down into its smallest units. Everyone points at music to illustrate this: explaining how MP3s, Napster and iTunes have turned the natural unit of music consumption into the song. And maybe that's commercially true. After all, there are lots of duff tracks on albums and sometimes you just want the best songs. But just because it's convenient for commerce and file storage, I'm not convinced the song is the natural unit of either production or consumption.

Getting a band in a studio is expensive and fiddly. Making the drums sound right and appropriate to the band's image, but slightly different to the last album and a bit like what the kids are doing these days, takes time. So once you've got all that done and got the musicians in one place and detoxed, sober and talking to each other, it makes no sense to record just one song and send them on their way. While they're there you should probably write and record a few; you might as well record an album. And then those songs are not completely separate entities, not isolated fragments. They're linked by sound, by the mood and ideas of the musicians, by the time and place of the recording. They're connected – and sometimes it makes sense for them to keep that connection.

And neither is the song the natural unit of music experience. We very rarely sit and listen to a single song, unless it's that first moment of fan devotion. We experience music as playlists, mixes, concerts, streams, shows, compilations and – yes – albums. We value the people who can do these things well – recombining the atoms of music into molecules of experience. And, slowly, after being torn apart by the web, those units of experience are emerging as units of consumption – newly configured to the digital world.

Look, for instance, at Boomkat Records' 14tracks.com website – a themed suite of music you can buy as a single package. How long before people are making money compiling Spotify playlists? Or before bands decide that they're only going to make albums available as single unbreakable files?

All of which meandering was prompted when I saw the marvellous new WIRED US iPad app. How, I thought, am I supposed to write for that? My words will end up on an iPad when the UK edition's app launches later this year, and I'm sure they'll be laid out in a gorgeous and appropriate manner, but you've got to wonder – what could I be doing with words that I can't do anywhere else? What's the right size for words on the iPad? How will they be recombined? How do they integrate with music and video? The joy of the iPad for publishers is control in a multimedia world – a control they lost on the web. This'll be a nightmare if they get it wrong – like horrible CD-Roms – but for the writer it could represent all sorts of possibilities. Just watch out if you're reading this on an iPad – I could be rickrolling you at your next swipe.

ILLUSTRATION: JOE SNOW

> START

MICROBIOGRAPHY
Russell M Davies previously worked in advertising, launching Microsoft Office and Explorer. He organises the London Interesting conferences and blogs at *russelldavies.com*

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PHOTOGRAPHY: ANDY BARTER

Turning data into speed

From its 4,600m² premises in Rye, East Sussex, JRM Group modifies and maintains Japanese sports cars from Nissan Skyline dragsters to GT-R racers – one of which won the Silverstone leg of the 2010 FIA GT1 World Championship. WIRED inspects their award-winning kit

JRM assesses this 2.2-litre four-cylinder engine as being capable of 1,800bhp

The rig is rated to a continuous 9,000rpm, or 11,000rpm in short bursts

Ultrasonic water-level meters stop the brake running dry and the engine over-revving

> START

1. Engine room

Running a motor on the engine room's SuperFlow SF-902 dynamometer reveals a wealth of information. To test power, the engine's drive-shaft spins within a water brake, which is fed with up to 46,100 litres an hour. The dyno measures the resistance of the brake against the engine, giving it the torque figure and the engine's horsepower. The most powerful motor so far measured was a 1,500bhp dragster motor.

Supplemental information includes fuel consumption, lambda (the amount of oxygen in the exhaust) and blow-by – how much pressure escapes from the cylinders into the crankcase, indicating lost power.

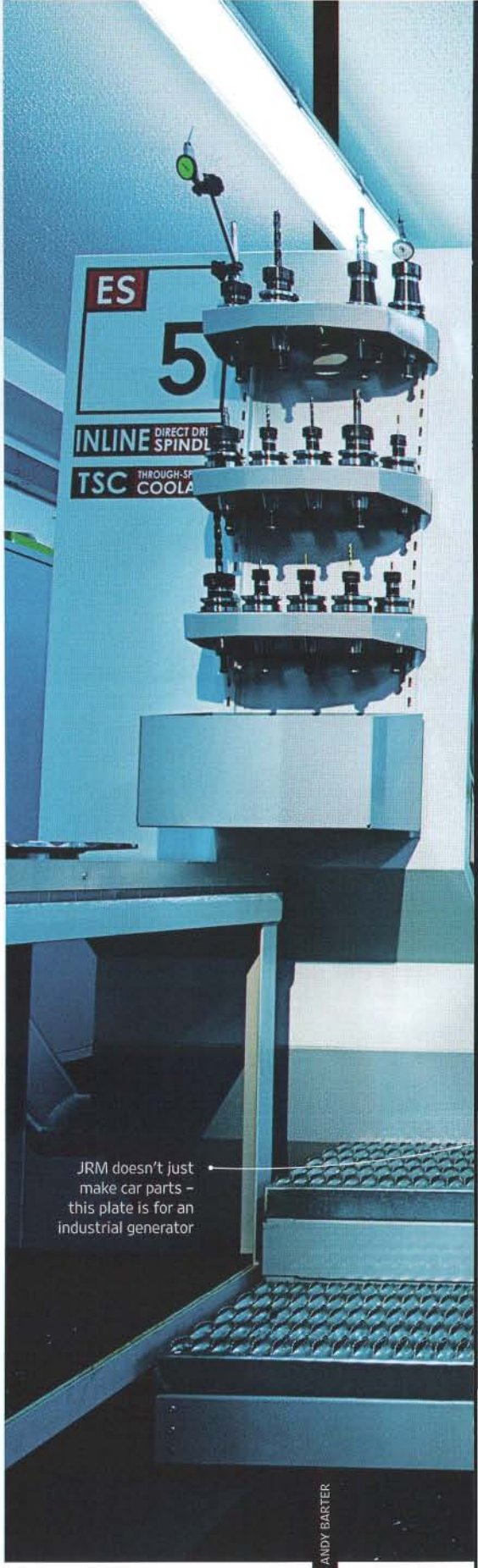
2. Rolling road

The engine room's dynamometer reveals the amount of power at the engine's crank, but to find out how much reaches the wheels (wheel horsepower – whp) requires a rolling road. Sumo Power GT's four-wheel-drive road can be used at up to 320kph and measures up to 1,500whp. A huge fan at the front simulates frontal air acting on the vehicle. This allows for accurate power measurement, as the air intakes and cooling systems are working as they would if the car was physically moving. The road is also used to tweak the engine management unit and for endurance testing.

3. Computed numerical control (CNC) machine

JRM's suite of CNC machines performs tasks from porting cylinder heads to making pliers. Simpler jobs are programmed with the control panel; more complicated parts are designed in CAD software and transferred on a USB stick. The mill selects the right tool from a 25-piece carousel and can compensate for wear – the position and state of the tool is displayed on the control panel's screen. The part being made and the cutting-bit are drenched with cooling fluid – without it, the tools wear excessively and may weld to the parts being manufactured.

Chris Finnamore



JRM doesn't just make car parts – this plate is for an industrial generator

PHOTOGRAPHY: ANDY BARTER


The rear-mounted carousel (not shown) can swap between tools in 2.8 seconds
The doors lock shut during machining to protect against flying coolant and swarf
Horizontal milling machines allow chips to fall away, leading to cleaner cutting
The spindle has 1,016 x 457 x 559mm of three-axis travel and spins at 8,000rpm
3
> START

Lab Notes #1: Positive Thinking

Our new column highlighting research you may have missed

"Believe in yourself" may be a cliché, but there's a growing mass of scientific evidence showing us just how much of a difference it can make. In studying negotiation, researchers at the University of California, Berkeley concluded that those who strongly believed they could improve their skills had better results across the board.[1]

At the University of Marburg in Germany, a study[2] showed that patients' beliefs about illnesses strongly affected how well they recovered from cardiac surgery: "The results suggest that patients could benefit from pre-surgery cognitive interventions aimed at changing maladaptive illness beliefs to improve physical functioning and disability following cardiac surgery."

The power of belief is so strong that by using the "placebo effect" to their advantage, doctors at the University of Rochester and Stanford have effectively treated psoriasis patients with half the standard dose of medication.[3]

Of course, it's not as simple as saying, "I believe X." A University of Waterloo paper[4] found: "Two experiments showed that among participants with low self-esteem, those who repeated a positive self-statement ('I'm a lovable person') felt worse than those who did not repeat the statement."

So, your belief must be sincere; but science is showing the leap of faith is worthwhile. *bakadesuyo.com* **Eric Barker**

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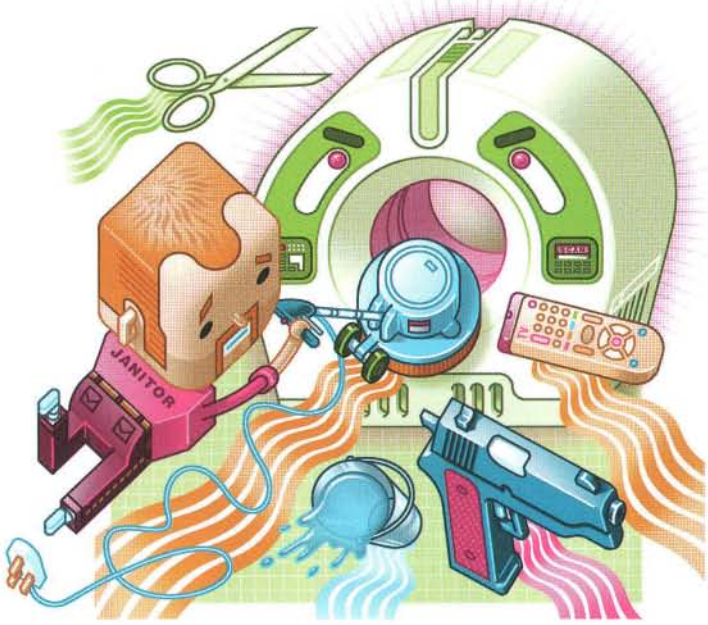


MRI's fatal attraction

Look out! It's the dark side of the magnetic force

"It's like Russian roulette, except that many don't know that they're even playing," says Tobias Gilk, a California-based MRI safety consultant. MRI scanners have electromagnets so powerful that they can dislodge pacemakers, suck in beds from across the room and turn small metal objects into dangerous "ferromagnetic projectiles". Gilk now collects data and reports of incidents at *mrimetaldetector.com/blog*. Here are six of WIRED's favourite MRI metal menaces. **Vaughan Bell**

1 Floor polisher

This is so common that the internet has whole galleries of trapped cleaning machines. Floor polishers end up stuck in scanners when cleaners stroll into MRI facilities out of hours and only realise they're in trouble when their equipment starts to gravitate towards the magnet.

2 Pistol

An MRI machine disarmed an off-duty US police officer. She forgot she was carrying her Glock pistol as she accompanied her mother, who was being scanned. The gun was pulled by the magnetic force, jamming her hand between the pistol and the machine and trapping the officer.

3 Scissors

An MRI technician ended up with a pair of scissors embedded in his forehead as he prepared a patient. Someone entered the scanner room with the scissors in their pocket – they were pulled out by the magnet and collided arrow-style with the technician's head.

4 Metal gurney

A patient and a metal gurney were both lifted off the ground and pulled towards the magnet as they were accidentally wheeled into the MRI room. The scanner had to be shut down in order to free the bed, and the unlucky patient suffered from foot, ankle and leg fractures.

5 Flat-screen

A member of the public who was inside the scanner solely for research purposes got badly injured when hospital staff walked a flat-screen monitor through the room. The magnetic field tried to put the screen and the participant in the same place; the next stop was casualty.

6 Wheelchair

A wheelchair brought into the danger area shot across the room and pinned a radiographer to the scanner. The staff member was unharmed but a patient waiting for her scan was so frightened she fell off the bed and broke her leg.

ILLUSTRATIONS: LEE HASLER, JEZ BURROWS

You have been pwned

Meet Nao, the little machine with a big future. He's designed to teach us, take care of us – and then, probably, replace us

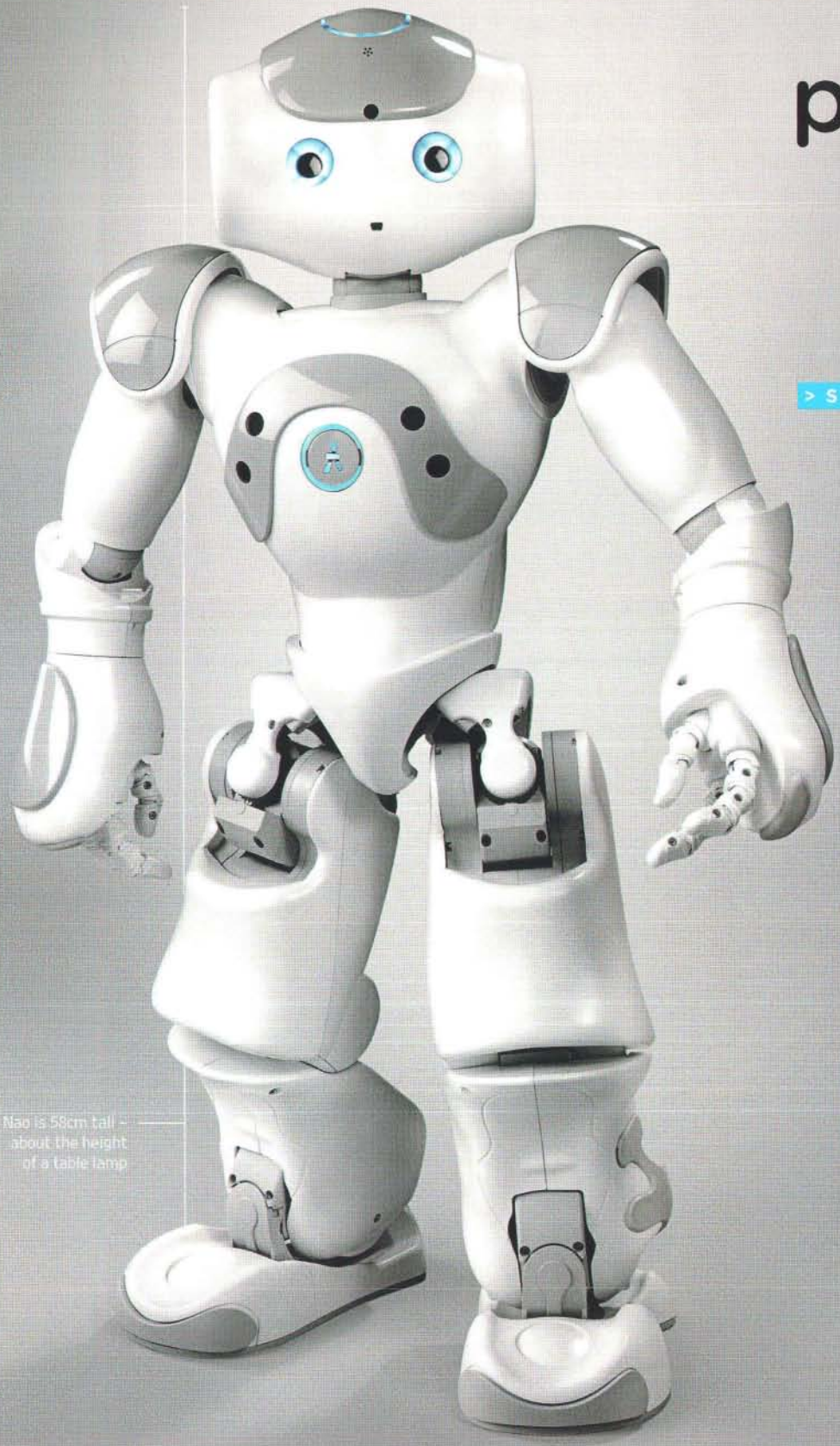
> START

Bruno Maisonnier believes machines are set to take over the world. He proclaims: "The year 2010 in robotics is the year 1980 in IT." Leading the revolution is Nao, a 58cm-tall robot created by Maisonnier's Paris-based company Aldebaran Robotics.

With a pair of three-megapixel cameras for eyes and four ultrasound echolocation sensors, Nao can navigate and interact with his surroundings. He can carry loads of up to 300g in his arms, using pressure pads and inertial sensors to keep his balance.

As well as recognising human faces and voice commands, Nao keeps in touch with machines using infrared and Wi-Fi connectivity, allowing him to work collaboratively with other robots to achieve difficult tasks.

Running on open-source software, Nao is a true polymath: he can dance, play football, help around the house and assist in autism research by interacting with autistic children using simple gestures and language. And in the future? Maisonnier sees Nao's next iterations caring for you in your old age. **Frank Swain**



Nao is 58cm tall – about the height of a table lamp

WARREN ELLIS

'TV as we know it is going away – and it won't come back'

Occasionally, I talk to people about writing for television. I think the only two things I've written that ever actually got aired were an episode of the *Justice League Unlimited* cartoon (notable only for the animation crew really going for it and the brilliant John C McGinley making me look like a genius) and a *GI Joe* animated miniseries thing (notable only for excellent direction and earning me the hatred of several hundred *GI Joe* fans).

But every now and then I sit down with the BBC, or with a production company, or with American network people, and talk about doing something. A friend of mine who works in the post-digital Silicon Roundabout "I dress like a homeless person but I really work in experience design" space has asked me over a pint at the dotcom-workdodger's pub, The Reliance, what on Earth I'm doing. "Television," he says. "Aerials and things. Rusting metal stuff. That's not right, is it? That's old. Why would you want to do that?"

And what I tell him is this: I'd like to do television before it goes away.

Classic television, if you like. Common-culture television, sprayed all over the country by, yes, big rusting aerials. Good old terrestrial television, even though the notions behind the term "terrestrial" have been pretty well eroded in recent years. That kind of television is going away sooner rather than later.

Oh, I'm sure there'll be a *Doctor Who* on a Saturday night, spinning a bejewelled fairy tale with one hand and selling a plastic sonic screwdriver with the other. There'll always be slews of reality shows for people to debase themselves on, as network TV continues its Cronenbergian mission to prove that nothing is real until it's on television. But the real cultural work of TV, the scripted stories – not so much.

Any show that isn't a soap opera "about relationships" gets put in one of those "weird" places where people who are less interested in crying and hugging go for a story – cable and satellite channels, or slotted in just before midnight and just after some programme about cocks, or (aha!) on iPlayer. Which is where Paul Cornell's rather good medical-horror *Pulse* gets to live or die. Since it was on BBC3, a channel only eight people in the UK can receive, the viewership it needs to get a full-series pick-up has to come from iPlayer. That's where the audience is – and it's where television is going to be.

Joss Whedon's *Dr Horrible* internet show got watched by a minimum of 2.2 million people in the five days it ran on the American iPlayer-ish Hulu service. For much of that time, the stream was locked to US-only computers. After that, you could only get it on iTunes for $3.99 a pop – and it sat at the top of the iTunes charts for some time. It didn't go anywhere near a TV screen until the DVD release.

The inspiration for doing *Dr Horrible* as television-not-for-television was Felicia Day's *The Guild*, a sitcom about online game-players, now shooting its fourth season. The first episode was "broadcast" by YouTube, where it has a current tally of over four million plays. Now you can find it on iTunes and Xbox Live.

There's money out there. This was the same money given to Radiohead and Trent Reznor for music, to Wil Wheaton for e-books. People are more comfortable with buying or renting digital goods – and they're certainly fine with streaming it for free and spending attention-economy currency on spreading the word and supporting the work.

Common culture is going away because the internet is so big and so full of shiny things pulling at our attention that it's now extremely difficult to get everyone's eyes on the same thing at anything like the same time. We exist in a state of cultural fracture, and the cracks are slowly but surely reaching through everything. It became TV's turn to start coming apart a while back.

We're surely at the cusp of the BBC shooting drama and comedy just for iPlayer. The Canadian sci-fi show *Sanctuary* jumping from the internet to cable TV is likely to prove as flukey as the Twitter account *Shit My Dad Says* getting a TV show.

So I'd like to do television now because it's a form I grew up with and I'd like a shot at standing on the same stage as the great television writers – the Dennis Potters and Troy Kennedy Martins and Alan Bleasdales – while I still can. Before it goes away and doesn't come back. It's a vanity, yes, but I'd like it.

But whatever comes next may be infinitely more interesting.

ILLUSTRATION: MIKEY BURTON

> START

MICROBIOGRAPHY
Warren Ellis is a prolific comic-book writer for Marvel and DC, as well as a novelist and commentator. You can read his blog at *warrenellis.com* and follow him at *twitter.com/warrenellis*

< Most pairs of underwear put on in 30 seconds: seven... >

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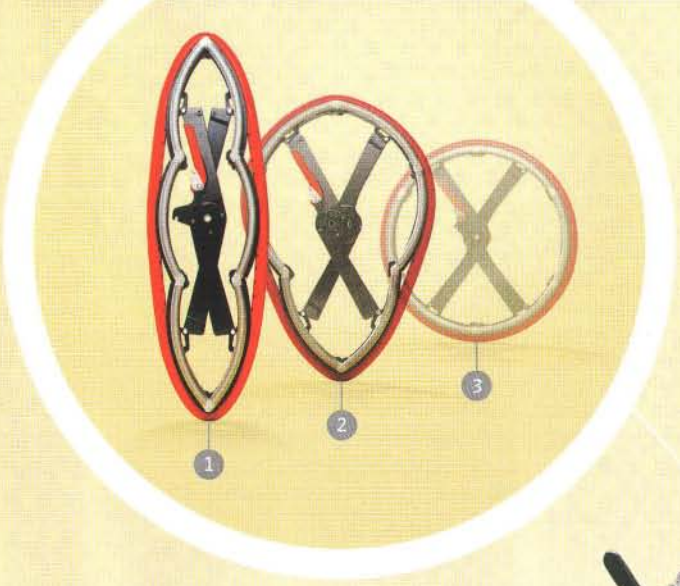
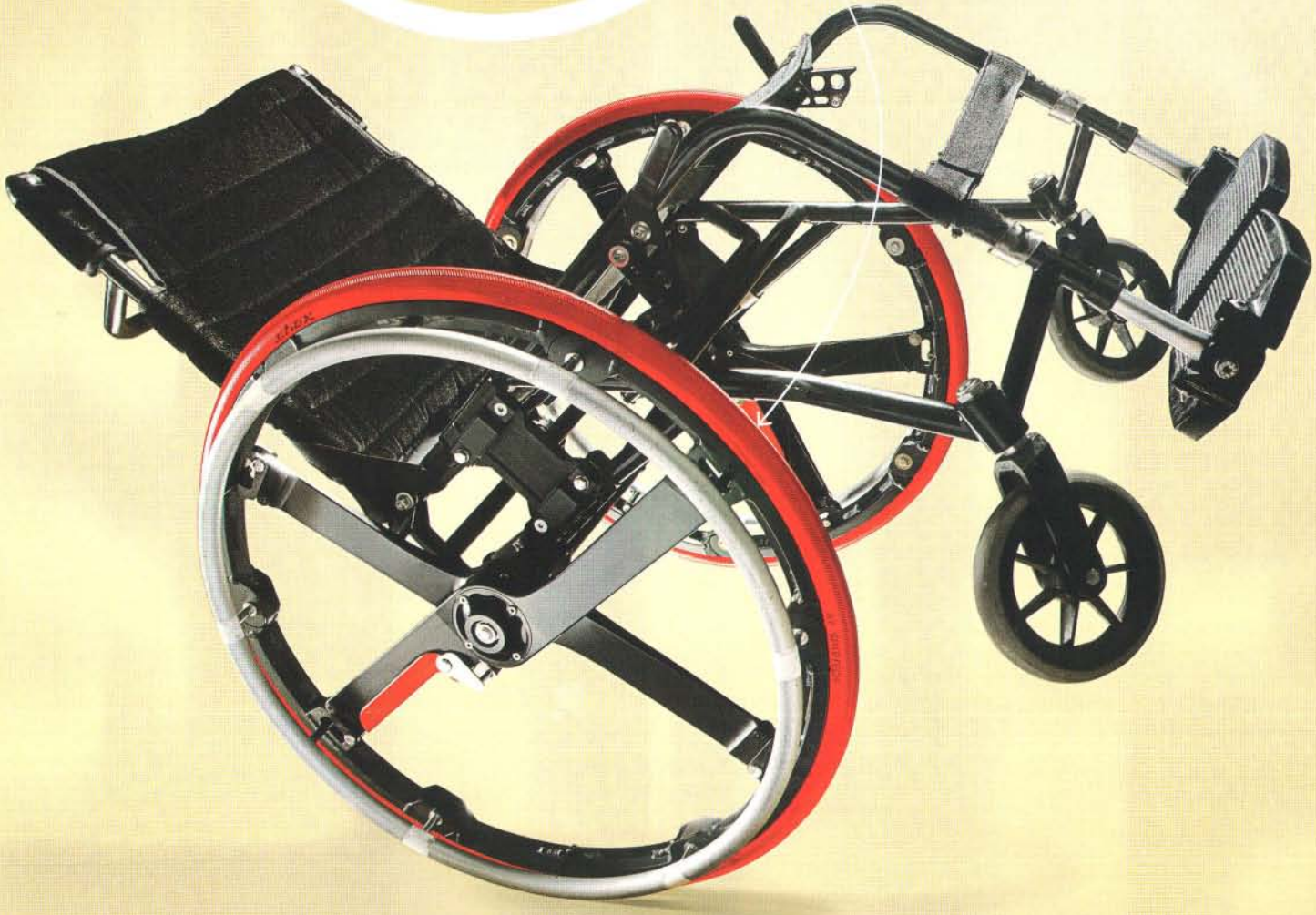


> START

The 61cm-diameter wheel folds down to an oval 25cm x 82cm so it can fit in a tennis-racket sized bag



Reinventing the wheel

Sometimes it can take millennia to improve on a classic – with foldability

Not every classic design can be improved upon. However, designer Duncan Fitzsimons's frustration with the perennial problem of stowing his bike has led to a smart breakthrough. "Foldable bikes with small wheels perform really poorly," he says. "Something had to be done." His smart solution? A foldable full-sized wheel.

With the collaboration of the Royal College of Art, the 28-year-old, based at Vitamins Design in London, created a wheel which uses two collapsible hinged spokes and a segmented rim.

Its first application is in foldable wheelchairs and it is compatible with available models. It goes on sale in 2011, at £1,000 a pair. Fitzsimons sees this as just the beginning – he hopes to get his aluminium wheel on to a planetary rover. **Herbert Wright**

< Most text messages sent to one person in five minutes: 230... >

Trend Surfing

iRentals

Not yet snagged an iPad to take on holiday? Qantas airlines has announced plans for its budget brand, Jetstar, to rent iPads in-flight, all preloaded with e-books, games, music and movies. Back on the ground, high-end hotel chain InterContinental is arming its concierges with iPads to give directions to local tourist attractions.

Couture hotels

Discerning travellers are now being wooed by luxury branded hotels. Gucci, Armani and Versace have all entered the stopover business, extending their deluxe design to everything from bell-hops to soap dishes. The three fashion giants have all launched hotels in Dubai – the Armani Hotel is in the Burj Khalifa, the world's tallest building.

Studio lines

Remember *The Truman Show*'s product placement? TV stations are evolving product lines featured in shows. Telemundo, a Spanish broadcaster, has telemundojewelry.com selling jewellery seen on the network's soaps. Teen drama *90210* is launching a clothing line on-air, sold in US Bebe stores. **Miriam Rayman and Estelle Ricoux**

Behold: das überbier!

A 43 per cent German lager briefly rules them all

To Georg Tscheuschner, a brewer in Oberasbach, Germany, Stella Artois's 5.2 per cent alcohol makes it a drink for weaklings. The mildest lager he makes is 13 per cent. "Alcohol in a beer increases the flavours just like fat does in meat," he says. So in keeping with his philosophy that more is more, Tscheuschner set out to produce the world's most powerful beer.

Schorschbräu Schorschbock 43 is a liver-melting 43 per cent alcohol by volume (as potent as whisky). Traditional fermentation can convert only so much sugar to alcohol, and using heat would ruin the carbonation. So the lager is stored at a temperature low enough for the watery parts to freeze, but high enough to keep the alcoholic goodness liquid. A 15-step filtering process reduces 350 litres to a super-concentrated 35 litres – enough to fill 100 0.33-litre bottles (€99 each – try *bierpost.com*). Tasters say it's "fruity and malty" with "a hot alcohol finish that burns your mouth".

Sadly for Tscheuschner, as WIRED went to press, his Schorschbock 43 was beaten by a Scottish beer with an alcohol content of 55 per cent (see *wired.co.uk* for more details). Its name? The End of History. Though, clearly, the very-strong-beer arms race has only just begun. **Rachel Swaby**

THE TROUBLE WITH IMMIGRANTS...

Alien species that came, saw and conquered

BROWN TREE SNAKE
(*Right*) Since arriving on Guam in post-World War Two cargo shipments, only half the native lizard species and two of 12 indigenous bird species remain.

CANE TOAD
Now widespread in Australia, this native of Central and South America shoots bufotenine toxin up to one metre and kills local snakes, lizards, dogs, cats – and even a few humans.

INDIAN MONGOOSE
This central Asian visitor is believed to have wiped out the bar-winged rail in Fiji, the racer snake on the island of Hispaniola and the Jamaican petrel bird.

BRAZILIAN PEPPER TREE
This tree inhibits native flora, thwarts bird nesting and has overrun swamps in Bermuda and Florida. Oh, and the toxic fruit can paralyse animals as big as a horse.

WALKING CATFISH
Native to south-east Asia, this fish wiggles along the ground to raid aqua-culture farms, wetlands, swamps and ponds up and down the east coast of the US.

YELLOW CRAZY ANT
An Asian export that sprays acid to subdue or exterminate prey. On Christmas Island it has decreased the red land crab population by 30 per cent. **Steven Leckart**

PHOTOGRAPHY: WILSON HENNESSY; CHRISTIAN STOLL; CORBIS

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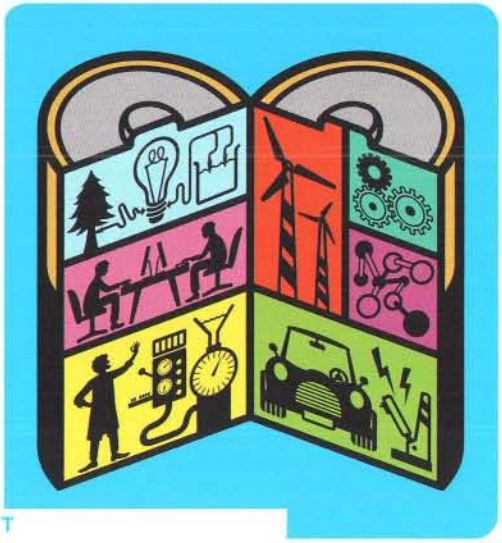

> START

Battery assaults

Who can keep our devices powered up for longer? Here are five teams leading the charge

Want to become the world's richest person? Invent a better battery. The tech world is crying out for more efficient ways to store electrical energy. Whether it's to make electric vehicles go further, or mobile phones charge more quickly, or to store grid energy from renewables, the market awaits. Here are five of the brightest sparks in development. **Duncan Graham-Rowe**

Liquid metal

Donald Sadoway, MIT

Made of molten layers of magnesium and antimony, these cells are more reminiscent of an industrial smelter than a battery. Even so, when separated by a layer of molten salt, the liquid metal layers behave like electrodes, storing up to 20 times more charge than traditional solid electrodes.

Future applications:

The shot-glass-sized prototype is now being scaled it up as part of a US Department of Energy project.

Carbon cells

Emile Greenhalgh, Imperial College, London

Combining structural form with electrical function, carbon-composite cells will bring us vehicles that store electrical energy in the roof, bonnet and other parts of the car's bodywork. In 15 years' time, this could reduce the weight of cars by up to 40 per cent.

Future applications:

He's currently working with Volvo – the current target is to reduce a car's weight by 15 per cent within three years.

Ultrafast nanoballs

Gerbrand Ceder, MIT

These lithium-ion batteries would make it possible to charge a mobile phone in just 30 seconds. Coating nanoballs in an additional thin layer of lithium phosphate speeds up the rate at which ions flow to and from electrodes. This reduces the charging time for a battery by a factor of 100.

Future applications:

Despite the lifestyle-changing capabilities of this kind of battery, significant investment would be needed to build charging devices.

Air breathing

Peter Bruce, St Andrews University

Normally the storage capacity of Li-ion batteries is limited by a bulky oxide material used to bind the lithium ions to the positive electrode. With Bruce's batteries air floods into the electrolyte solution, where it reacts with the lithium ions to bind directly to the electrodes.

Future applications:

Bruce says it should be possible to make batteries with ten times the traditional Li-ion power for mobile gadgets.

Robotic batteries

Better Place, Palo Alto, California

Not a new battery technology, but it could make electric vehicles more appealing. Instead of waiting for your car to recharge, an automated robotic platform replaces a depleted battery with a charged one. A station will launch in Denmark this year.

Future applications:

Already on its way. Renault will be releasing electric cars equipped with switchable batteries in 2011.

ILLUSTRATION: HANIBOI

WIRED	TIRED	EXPIRED
Revenue	Reach	Reputation
326dpi	300dpi	72dpi
Genetic steganography	Embedded RFID	Hallmarks
Immersive theatre	Hologram televisions	3D projectors
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DRIVE THE CHANGE

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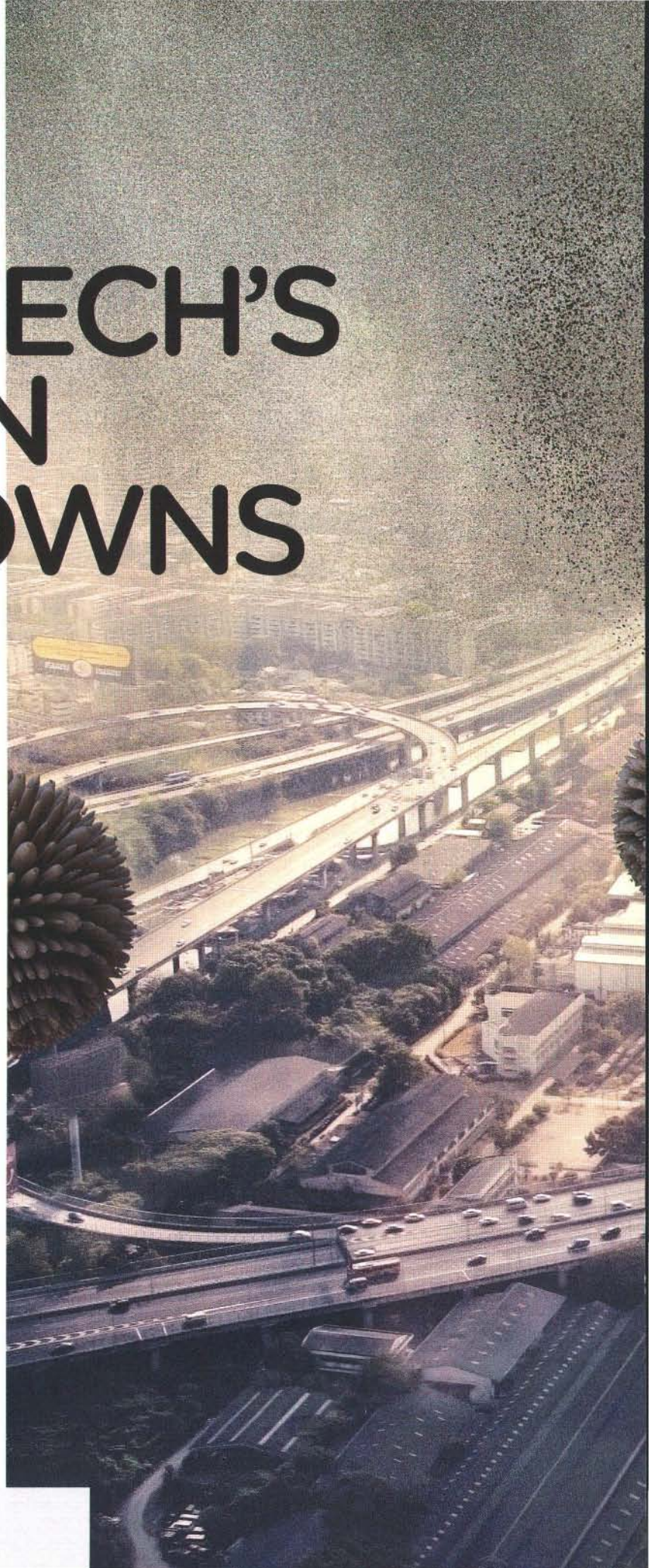
The official fuel consumption figures in mpg (l/100km) for the New Mégane Coupé-Cabriolet Dynamique TomTom range are Urban 25.9-46.3 (10.6-6.1); Extra Urban 44.8-64.2 (6.3-4.4); Combined 35.3-56.5 (8.0-5.0). The official CO_2 emissions range from 184 to 130 g/km.

NANOTECH'S KNOWN UNKNOWNS



Nanotechnology has a bad rep. But is it a potential killer in our midst, or a victim of outdated regulation and scare stories? By Frank Swain

Imagine if your company developed a fuel additive that could be mixed into regular diesel to change the way it burned, increasing the efficiency of an engine by more than ten per cent. Imagine that it also cleaned the engine and scrubbed the exhaust of carbon dioxide and soot. Imagine that these results could be achieved by adding just a few parts per million of this substance to a tank of fuel. You would expect companies in the US – the world's largest oil-consuming country – to be beating a path to your door, wouldn't you?

Professor Peter Dobson certainly thought so. The Oxfordshire company he founded developed Envirox, a cerium oxide-based fuel additive that does exactly that. The catalyst underwent successful trials in 2003 by a Hong Kong bus company before coming to the attention of transportation giant, Stagecoach, which implemented it across its 7,000-strong fleet of buses in the UK. Soon Envirox was in use in several countries, most recently debuting in Canada (in Stagecoach's Coach Canada buses) in December 2009.

When it arrived in the US in 2005, however, Dobson's mileage-boosting engine-cleaning fuel additive stalled. Despite Envirox being given a clean bill of health for the Environmental Protection Agency's (EPA) standard fuel-additives tests, the EPA then chose to invoke a further, non-standard set of tests. His company, Oxonica, simply could not afford

ILLUSTRATION: ZEITGUISED. PHOTOGRAPHY: MICHAEL BODIAM

this "open-ended" safety testing demanded by the EPA, an expenditure that Dobson says "only a major oil company could undertake". He's yet to see a single drop of his catalyst being used in vehicles on US highways, and doesn't expect to any time soon. Welcome to the uncertain business of nanotechnology.

The concept of nanotechnology was first postulated by physicist Richard Feynman in 1959, at a lecture at the California Institute of Technology. In it he described how one set of miniature tools could be used to build a smaller set, continuing the process downwards to individual atoms and molecules. The term "nanotechnology" didn't arrive until 1974, when it was coined by Professor Norio Taniguchi of the Science University of Tokyo.

The most workable definition describes a nanomaterial as having at least one dimension that measures between one and 100 billionths of a metre across, and exhibits novel properties because of this tiny size. A nanoparticle (such as a speck of soot) would be considered "3D". But the definition also covers "2D" nanomaterials such as surface coatings that are a few molecules thick, but might spread out to cover large areas, and "1D" nanowires that are nanoscale in diameter but can reach lengths 1,000 times this size.

Over the last two decades, nanotechnology has been embraced by the scientific, military, aerospace, chemical, manufacturing and pharmaceutical industries, and exploited for its advantages in food production, automobiles, clothing, building materials, packaging, electronics, cosmetics, paints, medicine and more. The US National Science Foundation estimated in 2000 that the nanotech market would be worth over $1tn by 2015, a figure later increased to $1.5tn by Cientifica, a Madrid-based tech consultancy with links to the European Space Agency. According to the House of Lords Select Committee on Science and Technology "Report into Nanotechnology and Food" (published in January 2010), the market is currently worth around $30bn per year.

Yet the technology's commercial growth has been accompanied by fears that it could damage human health and the environment. This in turn is stoking pressure on government and regulators to limit – even ban – a technology whose promise includes cleaner fuels, improved water filtration, better medicines, faster electronics and healthier foods.

As WIRED listens to Dobson, his frustration is clear. Unlike similar rare-earth elements, cerium oxide has no known adverse health effects, and has been incorporated into the fabric of self-cleaning ovens and catalytic converters. But the prospect of exhaust fumes carrying free particles of nano-sized cerium oxide into the environment does not sit well with the EPA. Dobson believes this is down to an irrational suspicion of all chemical products holding a nano prefix. "How many car-tyre manufacturers investigate whether tyre dust is safe?" he posits.

Dobson isn't trying to suggest that this obviates the risk of either being dangerous. He does, however, believe that the industry is being asked to provide levels-risk data that goes beyond that demanded from other manufacturers, to the point that it is hobbling innovation. This is partly the result of successful campaigning by some environmental groups against the fledgling industry. Dobson identifies the burden of evidence that companies working in novel technologies are expected to shoulder, saying: "It's easy to knock nano with statements which merely capture headlines." He complains that, although safety data is expensive and time-consuming to gather, accusations of potential ill effects are free.

It is estimated that the nanotechnology market will be worth over $1.5tn by 2015

He would instead prefer that regulators engage critics and adopt an evidence-based approach: "These people are holding us back and harming efforts to understand any adverse effects that nanoparticles might have. I believe there is a responsibility on the part of these people to get in there and have constructive dialogue with innovators."

Hilary Sutcliffe, director of Matter, a UK think-tank specialising in new technologies, has a different view. "On the whole NGOs have been responsible in their engagement so far. There are clearly uncertainties which need to be resolved and NGOs call for clarity about such risks," she tells WIRED. "However, if they are to remain credible with those who have access to information from a number of sources (such as our pilot website nanoandme.org), NGOs need to engage with real evidence and not cherry-pick data which may ultimately be misleading."

Professor Andrew Maynard issued a similar challenge on his blog, 2020science.org, to environmental group Friends of the Earth. Currently director of the Risk Science Center at the University of Michigan School of Public Health, Maynard has been active in nanotechnology science and policy for over 15 years. Responding to claims by Friends of the Earth that nanoparticles in sunscreen were harmful to humans, he asked: "What is your worst-case estimate of the risks from titanium dioxide and/or zinc oxide nanoparticles in sunscreens?" By focusing on this kind of tangible risk, he hopes to move the debate beyond fear-mongering. "What I am interested in is a number," he wrote. "A probability of a specific impact caused by using nano sunscreen over a period of time."

Within the UK and Europe, there is no single body tasked with regulating nanomaterials. This doesn't mean that the industry is unregulated; rather it is implicitly covered by a complex array of existing regulatory systems. The laws that govern the safe use of chemicals also cover nanotechnology. However, the concern is that these laws are ill-suited to deal with its unusual properties. Chemicals imported to and manufactured in Europe are subject to the remits of legislation known as Reach: the regulation on

Below: nano-silver particles. Its antibacterial properties mean it has been increasingly used in everything from children's toys to refrigerators

Registration, Evaluation, Authorisation and restriction of CHemical substances. Operating on a "no data, no market" premise, Reach requires essential information (such as physiochemical properties and toxicological effects) on substances to be disclosed. However, Reach does not differentiate between a bulk chemical and its nano-sized form, which in theory would allow a nanomaterial to be distributed under safety information that bears little relation to the material's known properties and toxicology.

The Reach statutes only apply to chemicals that are produced or imported above a threshold of one tonne. Producing a full chemical safety assessment is only required after crossing the ten-tonne threshold. By its nature, nanotechnology rarely leads to orders of this size. Legislators are currently working on ways to amend Reach to incorporate nanotech, but have stopped short of blocking products while they do so.

At its core, this is a debate about risk. Without reliable data, governments cannot take an informed view of a technology's consumer-health risks. Britain's Royal Commission on Environmental Pollution (RCEP) commented in 2008: "We are conscious of the extent to which knowledge lags significantly behind the pace of innovation." The government's UK Nanotechnologies Strategy, published in March this year, emphasises the need for stringent safety regulations and a more considered pace in developing new products and materials. Maynard commented on the UK strategy: "I advocate dealing with the potential adverse impacts of nanotechnologies. But developing a national strategy that is two-thirds focused on addressing potential risks seems a little over the top." Echoing sentiments expressed by Dobson, Maynard identified a gap between this industry's desire to prove safety and the development of a standardised framework to do just that. No one is in favour of a system where the first indications of a nanomaterial's toxicity are discovered in the environment or among humans, but equally no one is sure what the alternative is.

Foods provide a model for how nanomaterials pass into the human body. Nanoparticles that are insoluble can pass through barriers such as the gut wall, and have a tendency to accumulate in tissues. An example is colloidal silver, a suspension of silver nanoparticles popularised in the 90s by exponents of alternative medicine as a "natural" antibiotic. If consumed excessively it builds up, and has been known to cause fits, organ damage and permanent blue-grey discolouration of the skin.

A report released last year by the UK's Institute of Occupational Medicine warned: "Little is known in relation to consumer exposure, and work in nanoparticles and food seems to be missing." The Department of Health has committed £1.1m to researching the health impact of nanomaterials including carbon nanotubes (rolled-up sheets of carbon hexagons, each 10,000 times thinner than a human hair, discovered by IBM in 1991) and inhaled nanoparticles (under particular scrutiny due to the physical resemblance between high-aspect nanoparticles – those whose width or depth are considerably less than their length – and asbestos fibres). The first results are not expected until 2012.

In March 2010, the House of Lords Science and Technology Committee published the results of its year-long investigation into the use of nanotech by the food industry. Innovations in this field include plastic bottles of Corona coated with clay nanoparticles that act as a gas barrier, prolonging shelf life, and silica nanoparticles added to improve the taste of foods. However, the panel, led by the previous chair of the British Food Standards Agency, Professor Lord Krebs, criticised the food industry for maintaining a veil of secrecy over its use of such nanotechnology.

The British public have long distrusted innovations in food production. The introduction of mandatory milk pasteurisation in the UK, to stem some 2,500 deaths annually from bovine tuberculosis, was fiercely opposed during the 30s and 40s. Such attitudes – more recently manifest in hostility to genetic modification – may explain the reluctance of food-and-drink manufacturers to stoke public debate. However, Krebs argues that this strategy has a huge potential to backfire: "We believe that they should adopt exactly the opposite approach. If you want to build confidence you should be open rather than secretive."

Greater transparency may also offer a better strategy for developing a regulatory system in the absence of any solid data on the risks that nanomaterials pose. In late 2008, the RCEP voiced its support for such a system in a well-received report titled "Novel Materials in the Environment". The panel brought together scientists, lawyers, policy-makers and industry specialists to tackle the problem of regulating technologies that held what Donald Rumsfeld might call "unknown unknowns". Nanotechnologies were singled out not simply because of their novelty, but because of the huge range of potential applications and consumer products they promised to find use in.

The panel of experts concluded that, in the absence of known dangers, there is a need to be vigilant for unknown ones. And the best way of doing this is to keep a close eye on where exactly nanomaterials are being used. In the event that a nanomaterial is discovered to be harmful, a public database of all nanomaterials

> START

PICKING UP SPEED: NANOTECH USE IS SPREADING QUICKLY

At the 2008 Beijing Olympics, US athlete Jeremy Wariner ran the 400m relay wearing super-lightweight adidas Lone Star spikes (*above*). Built with carbon-nanotube-infused plates, they are 50 per cent lighter than his previous running shoes. In the UK, Continental is using the same nanoparticles to create soft, durable racing tyres, and Pilkington K has turned to nanotech surface coatings to create its self-cleaning glass.

and their usage would easily allow authorities to investigate where the material in question had been used. They could then act quickly to limit the production and release of such nanomaterial into the environment, and identify individuals likely to have been exposed.

However, attempts to build such a register have met with little success. A voluntary register of materials established by the Department for Environment, Food and Rural Affairs (Defra) received just 13 submissions between September 2006 and September 2008. Hilary Sutcliffe believes the nanotech industry needs to be more engaged. "Companies are going to have to bite the bullet and be much more open about their use of this technology. We hear so much about 'learning the lessons of GM' and see so little evidence of it actually happening," she says. "The public needs to see a clear benefit to society, to know that appropriate health, safety or environmental testing has been done. These are not unreasonable expectations, but we need innovative ways of making that happen which might take quite a few of us right out of our comfort zones into new ways of working and communicating."

Despite the recommendations of the RCEP, it's unlikely that regulators will move to make such a register compulsory. To begin with, nanotechnology is notoriously difficult to define. Although the working definition centres on a straightforward metric size in the range of one to 100nm, the reality is that particles exhibit nano properties over a wide range of sizes that can vary from one chemical to the next. This presents such a challenge that there is still no universally accepted regulatory definition of what constitutes a nanomaterial, and so it would remain unclear which products should be included. The production of ice cream and ricotta cheese both involve manipulating food on the nanoscale, but it's unlikely the Soil Association intended to ban these from the dinner table when it called for a moratorium on nano-derived foods in 2008.

To complicate matters, some nanoparticles are "doped" by applying other chemicals to their surface, so the same particle is engineered to behave in a different way. Another problem is one of enforcement. Detection of nanoparticles is still in its infancy – any test has to distinguish between man-made nanomaterials and naturally occurring particles such as soot. Plus, these are nascent industries with the potential to boost the UK economy. The government is unlikely to put into place any onerous regulation that might cause nanotechnology firms to take flight abroad.

Media coverage of GM food has engendered public mistrust of science

Rob Aitken believes these fears shouldn't preclude us from developing new nanomaterials. As strategic director of the Institute of Occupational Medicine in Edinburgh, he has worked with industry and government to provide advice on toxicology studies and nanotechnology research. He tells WIRED: "Many of the nanomaterials that come on to the market will have very few problems associated with them, but some will. Part of the difficulty is knowing which is which at the moment." But he also points out that we have been using nanotechnology for a long time. The carbon black used in the ink to print this article is an example of a nanomaterial that has been around for 40 years without presenting any significant health threat. "There is a lot of research going on, but the problem is that it has not been well co-ordinated at a national or international level," Aitken says.

To manufacturers and consumers, the rise of nanotechnology is an exciting and dramatic innovation with huge potential. The possible risks linger at the end of the table, intangible and indistinct – the ghost at the feast – a guest that no one is sure how to accommodate.

Frank Swain is a Liverpool-based writer and public speaker specialising in science

THE WIRED INDEX

45%

Proportion of US population that said it read at least one book last year

109 YEARS

Length of time the longest running light bulb in the world has been burning. It is housed in Livermore Firestation No 6, California

146

A "head-banging" song's tempo, in BPM, that is likely to cause dizziness when motion range is greater than 75°, according to the *British Medical Journal*

$13BN

How much an iPod would have cost in 1976, due to the price of transistors. It would also be the size of a building

1 BILLION

Number of transistors per person in the world today

THIRTEEN

Number of days to reach one million Nintendo Wiis sold

28

Number of days it took Apple to sell its first one million iPads

For sources, see page 146

> START

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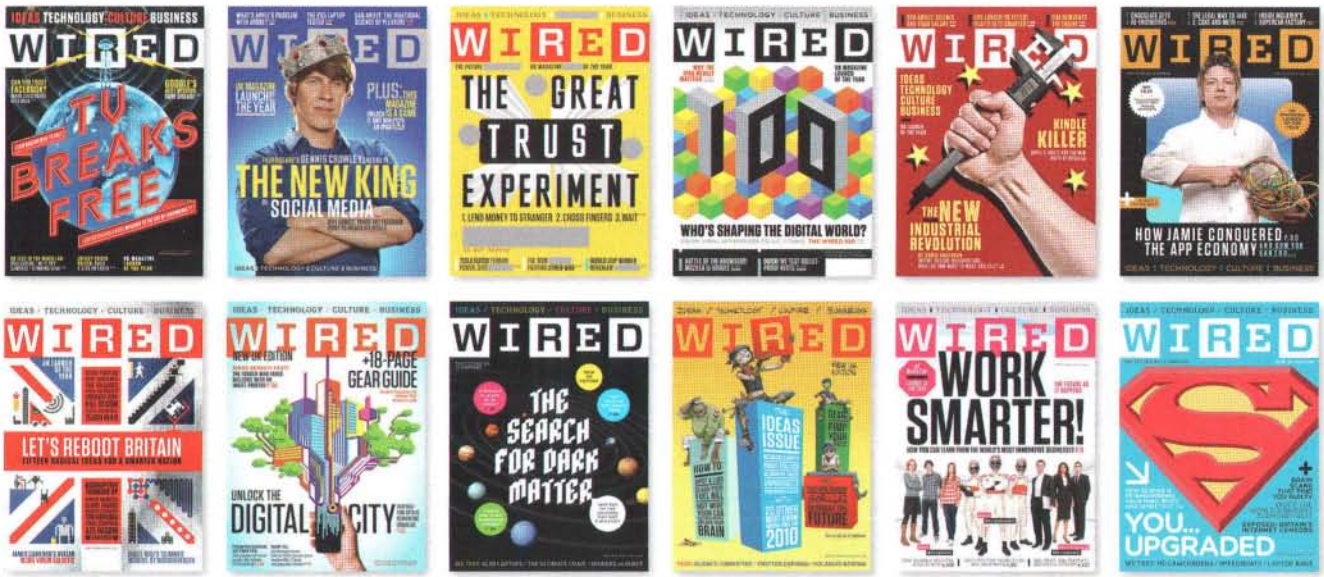

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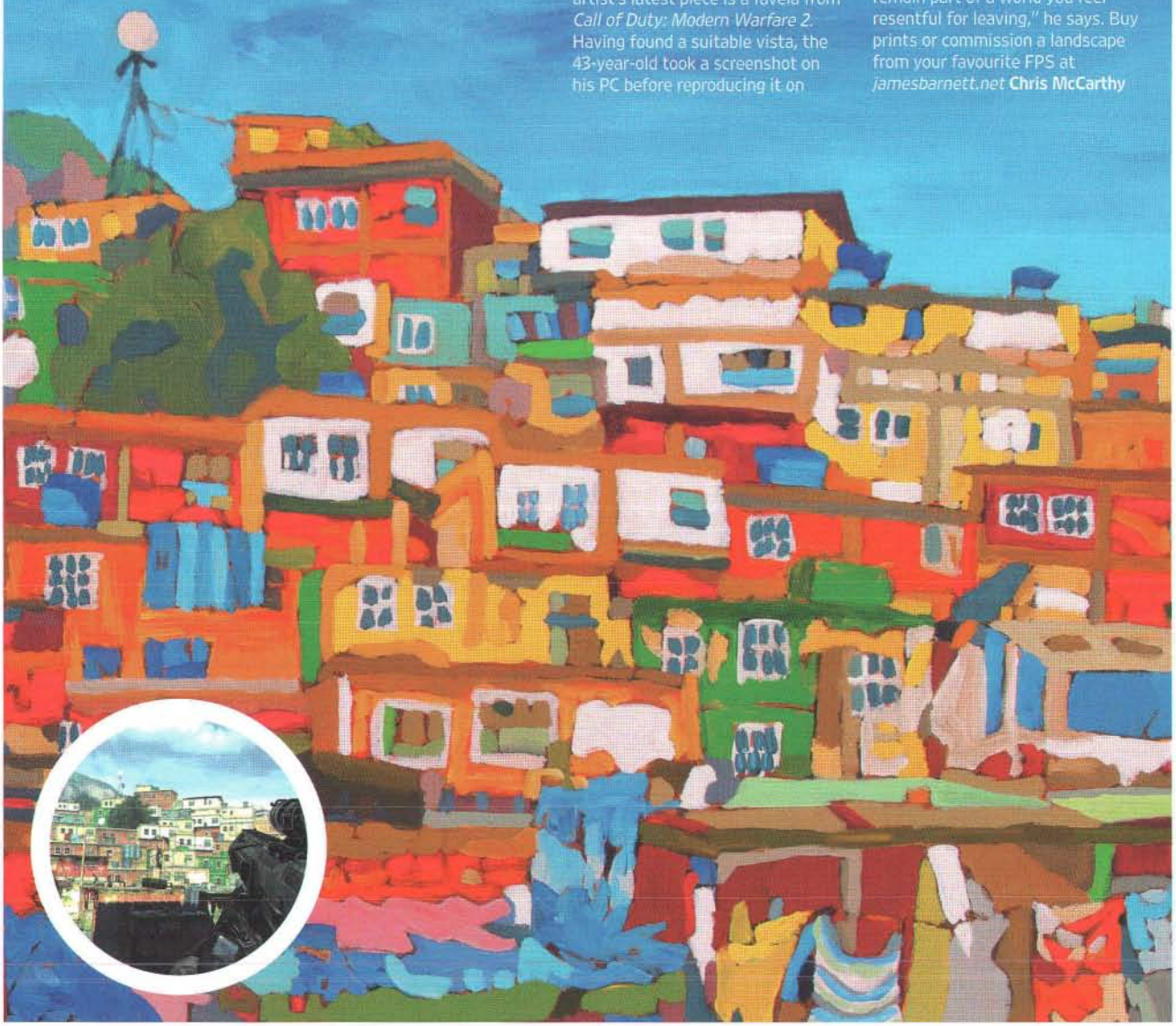
EDITED BY CHARLIE BURTON

VIRTUAL LANDSCAPES

James Barnett began painting scenes from video games when web-design work dried up during the dot-com crash of 2000 – and he hasn't stopped. The Arizona-based artist's latest piece is a favela from *Call of Duty: Modern Warfare 2*. Having found a suitable vista, the 43-year-old took a screenshot on his PC before reproducing it on canvas in candy-bright hues. His hobby has become an art series he dubs "Fauxvism", and he has completed 30 in-game paintings. "These paintings allow you to remain part of a world you feel resentful for leaving," he says. Buy prints or commission a landscape from your favourite FPS at *jamesbarnett.net* **Chris McCarthy**



The jelly dealmakers

Bompas and Parr turn food into art – from levitating chips to breathable fruit

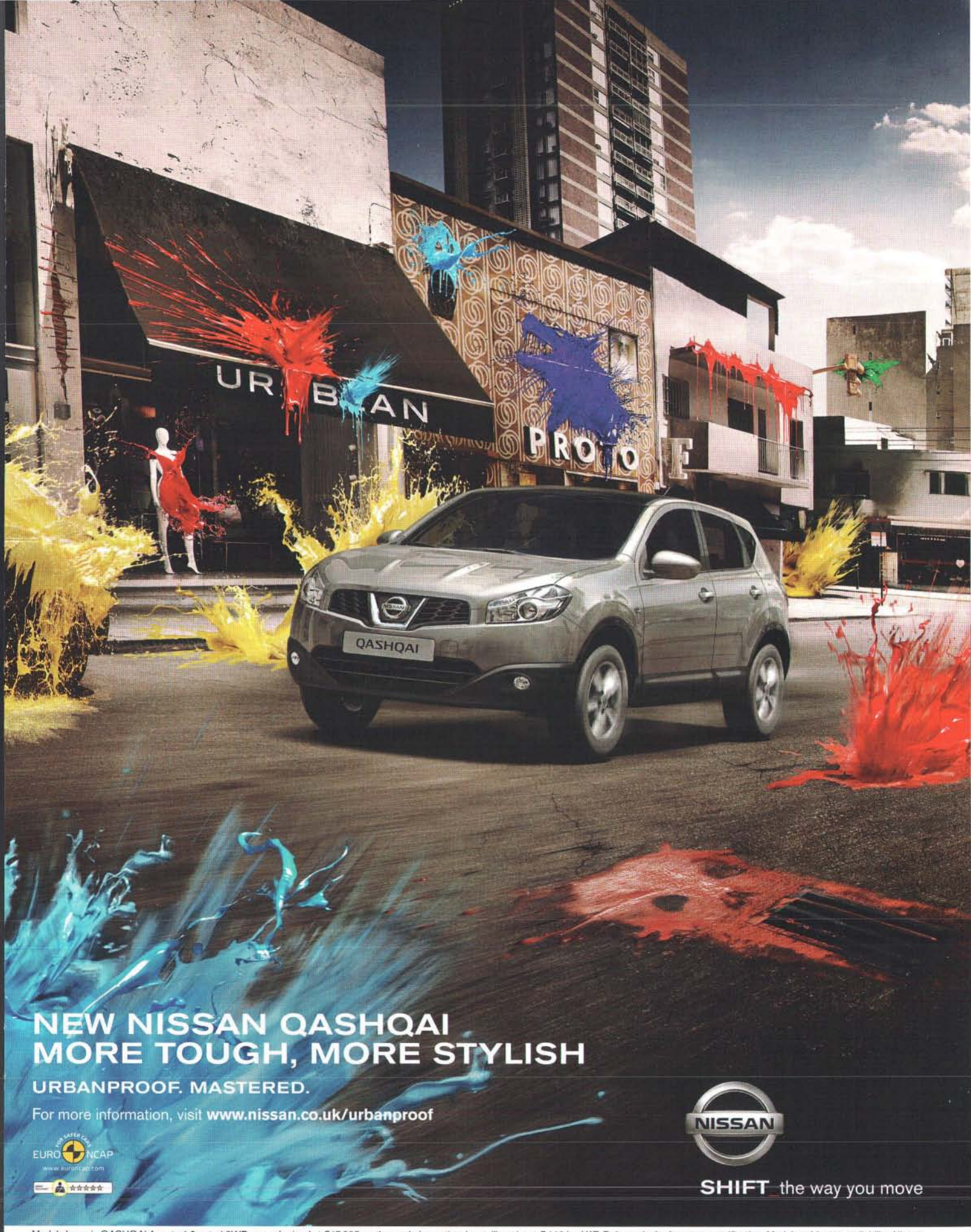
Last year, culinary artists Sam Bompas and Harry Parr made a giant punch bowl containing 4,000 litres of brandy cocktail. Other projects that year ranged from breathable gin and tonic to a Futurist-themed dinner punctuated by explosions. So when they reveal plans for a banquet of levitating food, you know they're serious. "We're looking at mag-lev: if you're using superconductors you can get a stable field," says 26-year-old Bompas. "So far we've got a chip to float."

Having met at Eton, the pair started business life making bespoke Victorian jellies. In 2007 Warwick Castle commissioned one in the shape of the building, but at the time Bompas and Parr couldn't deliver it (instead they prepared a 12-course 19th-century breakfast). But now "figurative food" is their calling-card, employing 27-year-old Parr's experience as an architect in their use of CAD software and rapid prototyping to create the moulds. Recent works have included edible miniatures of Madrid's Barajas airport and London's Millennium Bridge. "We spend 30 per cent of our time on food and 70 per cent on the rest – how it looks and sounds, and what else is going on around you," says Bompas.

To experience such theatrics first-hand, this summer's Big Chill festival (August 5-8) in Hertfordshire will feature their "Ziggurat of Flavour" – a pyramid holding a cloud of breathable fruit. No word on whether it's one of your five-a-day. *jellymongers.co.uk* **CB**

SAM BOMPAS AND HARRY PARR AND JELLY

PHOTOGRAPHY: LEE POWERS



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Model shown is QASHQAI Acenta 1.6 petrol 2WD manual priced at £17,295 on the road plus optional metallic paint at £440 inc VAT. Refer to dealer for exact specification. Models subject to availability. Nissan Motor (GB) Ltd, The Rivers Office Park, Denham Way, Rickmansworth, Hertfordshire, WD3 9YS.

Fuel consumption figures for Nissan QASHQAI Range: CO_2 130-191g/km – URBAN 26.6-50.4mpg/10.6-5.6L/100km – EXTRA URBAN 43.5-62.8mpg/6.5-4.5L/100km – COMBINED 35.3-57.6mpg/8-4.9L/100km

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Pre-production fuel consumption figures for Juke range are: URBAN 44.8-27.7mpg/6.3-10.2L/100km. EXTRA 134-175g/km. Correct at time of print. Official figures available at www.nissan.co.uk from August 2010.

NISSAN

SHIFT_the way you move

010868B

URBAN 64.1-47.0mpg/4.4-6.0L/100km. COMBINED 55.3-37.2mpg/5.1-7.6L/100km. CO_2 emissions are:

The film of the untold Pilgrim

Director Edgar Wright has adapted the Scott Pilgrim graphic novels for the big screen – before they were all even written

"Two producers came to a screening of *Shaun of the Dead* and said, 'We have the perfect project for you.' It turns out they were right, which very rarely happens." Six years on, British director Edgar Wright (*right*) has brought *Scott Pilgrim vs The World* to the silver screen.

Bryan Lee O'Malley's *Scott Pilgrim* comic books – tales of a twenty-something slacker's quests to defeat his girlfriend's seven evil exes – had already won a dedicated following. Their magical realism and video-game-inspired fight scenes made Wright, veteran of Channel 4's *Spaced*, a perfect fit to adapt them. There was only one problem: when he signed up, only two of the six books had been written. So how do you adapt a story that doesn't exist?

"When I started the project, there were just two books and the biographies of the other evil exes, so I and [co-writer] Michael Bacall went to Toronto to pick Bryan's brains," Wright explains. "We got synopses, which got more and more vague as we got towards Book Six. Now there are parts where we can't remember who wrote what, and neither can Bryan."

Wright's "kitchen sink" first draft leaked on to the internet – and then back into O'Malley's brain. "There are lines in the fourth and fifth books where Bryan has very sweetly emailed to say, 'Hey, can I steal that line?' And we were like, 'Of course! It's yours!'" The influence extended as far as O'Malley's choice of writing software – after seeing the script being crafted on Apple's Final Draft, he was inspired to use it to craft the final books in the series.

The fans of the books have been supportive – for the most part. There was some outcry when Michael Cera (*Arrested Development*, *Superbad*) was cast as Scott Pilgrim. "Someone on Twitter said Michael Cera's eyes weren't big enough," says Wright. "His eyes are huge! Find me an actor with bigger eyes!"

Nonetheless, fan anticipation is high as the final book and the film arrive together, with the pair of big-eyed Pilgrims looking out from different but familiar worlds.

"Bryan's seen the film – he likes the bits that aren't in the books the best; he gets a kick out of seeing a bizarro version. It's more like a classic kung-fu film crossed with a romantic comedy. Somewhere between *Five Fingers of Death* and *Pretty in Pink*." **Daniel Nye Griffiths**

Scott Pilgrim's Precious Little Life *by Bryan Lee O'Malley is out now (£7.99, Fourth Estate).* Scott Pilgrim vs The World, *directed by Edgar Wright, is in cinemas from August 27.* scottpilgrimthemovie.com

PHOTOGRAPHY: ERIC RAY DAVIDSON. ILLUSTRATION: BRYAN LEE O'MALLEY

COMIC-BOOK COMPARISONS: HOW WRIGHT MATCHED IT UP

COMIC FILM

Scott (Michael Cera) "air juggles" evil ex #1, Matthew Patel (Satya Bhabha): "Kevin Smith said that Michael Cera plays it like he's Bugs Bunny," says Wright. "He's indestructible and mischievous. You cannot beat him. He just gets back up."

The characters imitate the eyes of their graphic counterparts: "I told Mary [Elizabeth Winstead] how to do her 'anime' look – be looking one way, then flick your eyes the other way. She does that a lot, and it's perfect."

Wright kept the comic books' emotive symbols: "When they fight, or when they kiss, its an explosion. If you were actually there with a camera, it would be a normal kiss, but this is the movie in Scott Pilgrim's head."

The film's opening battle plays out like a beat-em-up video game: "It's a gamer's fantasy – you're not a model of athleticism, but you're thinking: 'If I'm really good at *Tekken*, why can't I also be really good at fighting in real life?'"

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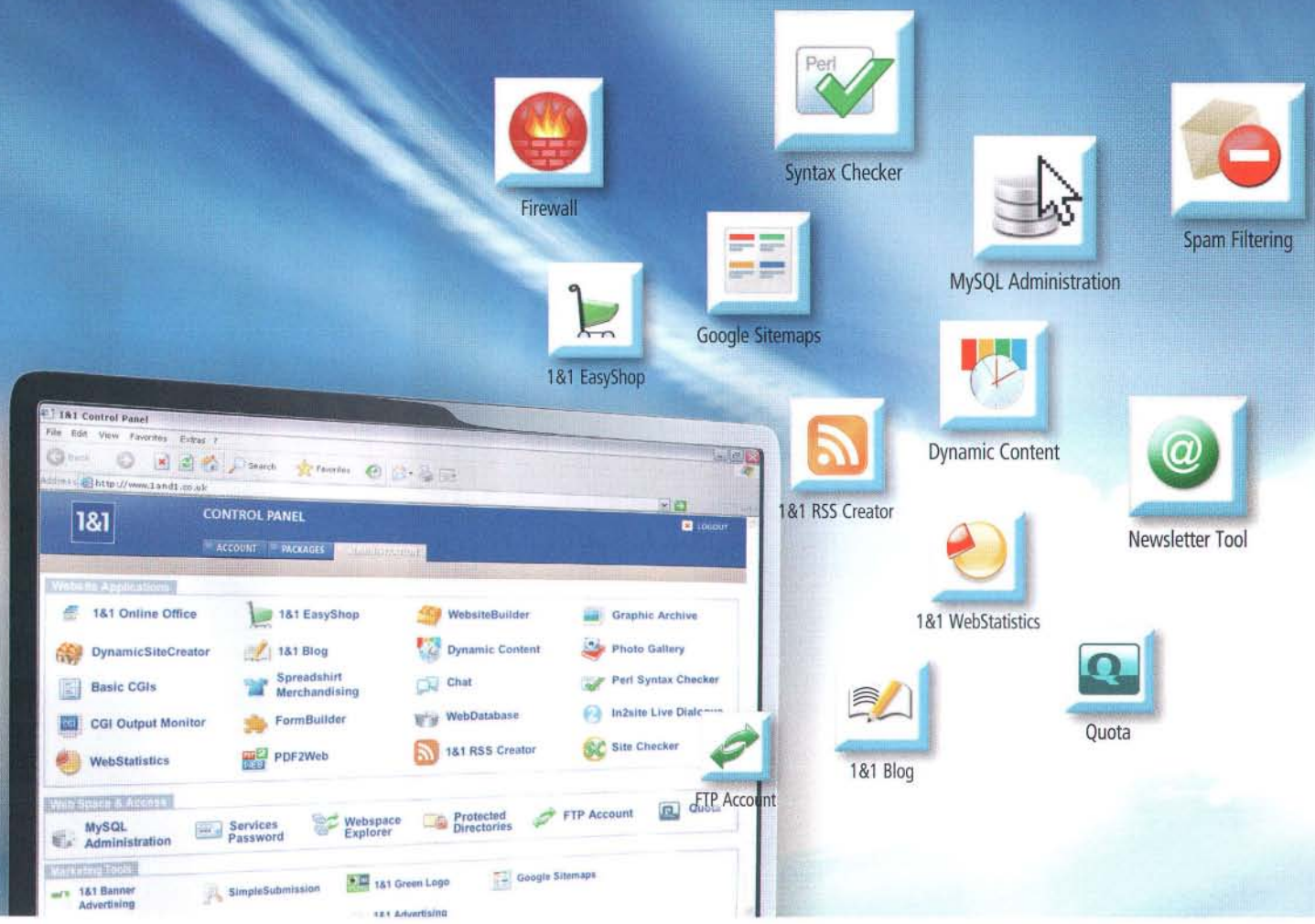

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Braaaains... and book deals

Forget vampires – can you survive an outbreak of zombie writing?

Could the bloodsuckers' domination of literature be drawing to a close? It seems so – zombies have been gaining traction since *Pride and Prejudice and Zombies* (Quirk Books, 2009), and with no new books planned for the sparkle-vamp franchise, there's an opening in the market. From this summer, small bands of survivors will be fighting for their lives against a variety of reanimated corpses. Here are a few of the titles we'll be feasting on. **Alison Flood**

***FEED*, BY MIRA GRANT**

The cause of the trouble: The zombie virus is created after a cure for the common cold gets released into the air and reacts with a cure for cancer. When the virus amplifies through death of the host, or contact is made with zombie bodily fluids, zombification occurs.
Known as: The Kellis-Amberlee virus
Meet: Young bloggers Georgia and Shaun Mason, who are on the trail of the truth.
Romero rating: 4/5. The feisty blogging news-hounds and a snarky tone are fun.
Out: Now

***ZOMBIE APOCALYPSE!* CREATED BY STEPHEN JONES**

The cause of the trouble: Excavating a church that was built on the site of a 14th-century plague pit.
Known as: The Death
Meet: Thirteen-year-old diarist Maddy and academic Professor Margaret, who opposes the excavation.
Romero rating: 4/5. Told via blogs and tweets, this a zombie apocalypse for the web generation.
Out: October 14

***WARM BODIES*, BY ISAAC MARION**

The cause of the trouble: It could be a disease, a curse or something darker – our protagonists aren't quite sure.
Known as: The Plague
Meet: The wistful, lonesome zombie "R" and Julie, the human he saves – did you get the reference?
Romero rating: 3.5/5. Dark and funny, this is billed as a zombie romantic comedy – and it actually works.
Out: October 28

***AUTUMN*, BY DAVID MOODY**
The cause of the trouble: A virus kills billions within 24 hours by causing the lining of the throate to swell and the victim to suffocate. You're either immune, or you're not. If you're not immune you die – and then come back.
Known as: Our heroes aren't too sure...
Meet: Carl the mechanic, Emma the trainee doctor and Michael the teacher.
Romero rating: 3/5. This is classic holding-out-against-the-undead fare, but there's little gore and no flesh-eating.
Out: October 2010 (first in a series)

***PLAGUE OF THE DEAD*, BY ZA RECHT**
The cause of the trouble: Originating in the jungles of Africa, the virus infects through bodily-fluid contact and turns the infected violently homicidal. Death is followed by reanimation.
Known as: The Morningstar strain
Meet: Lieutenant-colonel Anna Demilio – a US Army infectious-disease specialist, major-general Frank Sherman, journalist Julie and volunteer Rebecca.
Romero rating: 2.5/5. For those intrigued by how the US Army handles zombies.
Out: Now

ILLUSTRATION: BILL MCCONKEY

[PLAYDESIGN

A WELL-SPUN SEAT

This chair doesn't just look like a spinning top: it works like one too. "Spun" is the latest creation from the studio of Thomas Heatherwick, who designed the British pavilion for this year's Shanghai Expo (see issue 06.10). "We wondered to ourselves, could you make a completely rotationally symmetrical object?" says Stuart Wood, the project's designer. "Could you make a piece of furniture where you could take one profile, rotate it around, and that would completely fulfil all your needs?"

The chair took months of prototyping and several iterations due to its symmetrical form: "Once you apply, say, a millimetre below the bum, you have to do it behind the back too. It's a constant balance back and forth until you hit the sweet spot. The result is extremely efficient – it's like Darwinian evolution." Spilled on to its side, the finished chair offers a comfy seat. Retract your legs inside, though, and you can roll it around, perfectly balanced.

The chair is available as either a one-off metal edition, handmade using metal-turning techniques usually employed in making kettle drums, or in mass-produced unibody plastic form (from Italian furniture manufacturer Magis) created by rotational moulding. "The name," says Wood, "is completely appropriate." *heatherwick.com* **TC**

WIRED INSIDER

Events, new products, promotions and competitions to help you live the WIRED life

Compiled by Nicola Day

VERTU ASCENT X

The Ascent X is the latest handcrafted luxury mobile phone from Vertu and bears the hallmarks of quality design and construction you would expect from a product created by Frank Nuovo, the principal designer at Vertu.

Each Ascent X handset employs a rich set of materials including aerospace-grade aluminium, titanium, rubber and even leather (*such as the red-leather trim model, left*). Its design influences draw on motor racing, military aviation and stealth technology. Nuovo describes the look as being "direct and literally to the point... it's the tip of the spear" – we can't help but agree.

And it isn't just beautiful to look at: its use of high-grade elements throughout, such as heat-treated and anodised aluminium, makes for a truly tough phone that can handle anything your lifestyle throws at it.

Specifications include a two-inch sapphire-coated QVGA screen, a five-magapixel camera with flash and autofocus, 32GB of internal memory and quad-band 3G/GSM network coverage.

But what really sets the Ascent X apart is the Vertu concierge service. Just a call away is a dedicated team who can book travel, entertainment, accommodation – even a reservation at your favourite restaurant. Now that's what we call truly luxurious. *For more information, visit vertu.com*

DUNHILL PEN

The Sentryman Explorer II is the second piece in Dunhill's Explorer collection. Highly exclusive – there are only 150 – the gunmetal-grey carbon-fibre barrel of the pen features a hidden extra: remove the end and it has a built-in torch. The pen also has three interchangeable nibs – an 18-carat gold fountain-pen nib, pencil or ballpoint. *For more, go to dunhill.com*

EXCLUSIVE TEDGLOBAL COVERAGE

All fans of ideas should follow WIRED's exclusive coverage of TEDGlobal, in association with IBM, which took place in Oxford during July. Our October issue will include an eight-page TED round-up featuring insights and commentary. Plus, running from November to April, we profile the next generation of influential thinkers and doers, the TED Fellows. Further coverage of the talks is available online at *wired.co.uk*, with videos, interviews, facts and more. *For further details on TED visit wired.co.uk/news/ted-news*

TREK BIKES

Calling all serious cyclists: Trek, the nine-times Tour de France-winning company, has a new series of Madone road bikes. Top of the list is the 6 Series SSL. Using the latest carbon-fibre technology, OCLV HexSL carbon, means the frames are four times stronger than the previous iteration, and weigh 100 grams less. Available through Trek's custom-bike programme, "Project One", riders can fine-tune virtually every aspect of the bike. *Starting price of £6,750. For information visit trekbikes.com/madone*

BVCA TALKS

UK entrepreneurs and investors meet at the British Private Equity and Venture Capital Association conference, held in Manchester on September 16. WIRED's editor, David Rowan, will be taking part in discussions on finance and funding in the digital age. *Go to bvcadigitalage.com to find out more*

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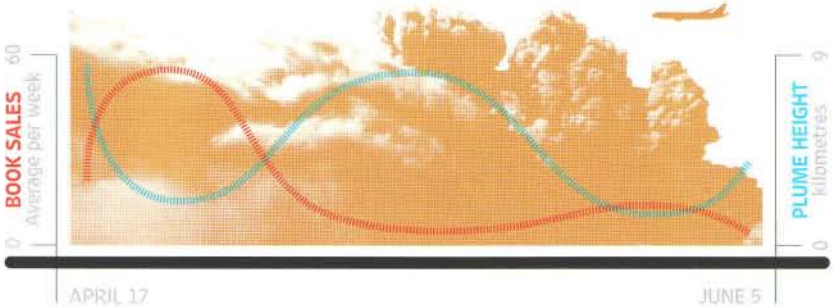
MOVIE MATHS WITH SLY AND ARNIE

It's either a sign of the End of Days or the Greatest Thing Ever, but Sly Stallone's latest film, *The Expendables*, has assembled all the survivors of 80s action-moviedom (plus some new-ish blood), so you know it's going to be *awesome*. Here, our equation works out who's really expendable – and proves an obscure 1995 Brigitte Nielsen film is the nexus of the 80s action universe. Mike Ryan

	BIGGEST GLOBAL ACTION FILM		WEAPON OF CHOICE		RELATIVE PROXIMITY TO BRIGITTE NIELSEN		UNEXPENDABILITY QUOTIENT
DOLPH LUNDGREN							
	***Rocky IV* (£198 million global box-office)**	+	Boxing gloves and Soviet steroids	÷	**Fictionally married to Nielsen in *Rocky IV***	=	The definition of expendable
JET LI							
	*Lethal Weapon 4* (£188 million)	+	**Fists, sometimes a sword**	÷	Appeared in *Cradle 2 the Grave* with Woon Young Park, who starred in *Galaxis* with Nielsen	=	**Rather expendable**
JASON STATHAM							
	***The Italian Job* (£115 million)**	+	Audi A8 W12	÷	**Starred in *The Bank Job* with Craig Fairbrass, who starred in *Galaxis* with Nielsen**	=	Moderately expendable
SYLVESTER STALLONE							
	*Rambo: First Blood Part II* (£198 million)	+	**M60E3 machine gun**	÷	Real-life two-year marriage to Nielsen	=	**Only slightly expendable – this is his film, after all**
MICKEY ROURKE							
	***Iron Man 2* (£395 million and rising)**	+	Electric whips powered by an arc reactor	÷	**Was in *Masked and Anonymous* with Michael Paul Chan, who starred in *Galaxis* with Nielsen**	=	Surprisingly unexpendable
ARNOLD SCHWARZENEGGER							
	*Terminator 2: Judgment Day* (£341 million)	+	**Sawn-off Winchester 1887**	÷	Featured with Nielsen in *Red Sonja*, including challenging her to a passionate duel	=	**Unsurprisingly unexpendable**
BRUCE WILLIS							
	***Armageddon* (£365 million)**	+	Beretta 92F	÷	**Appeared in *Loaded Weapon 1* with Richard Moll... who starred in *Galaxis* with Nielsen**	=	Least expendable

SPURIOUS SCIENCE: VOLCANO BOOKS

Eyjafjallajökull didn't just eject ash – it boosted book sales. WIRED plotted the average sales of three related children's science books – *Usborne Beginners: Volcano*; *I Wonder Why Volcanoes Blow Their Tops* (Kingfisher); and *My Best Book of Volcanoes* (Kingfisher) – against the daily height of the ash plume as recorded by the Met Office. Happy airport reading. **Jennifer Lucy Allan**



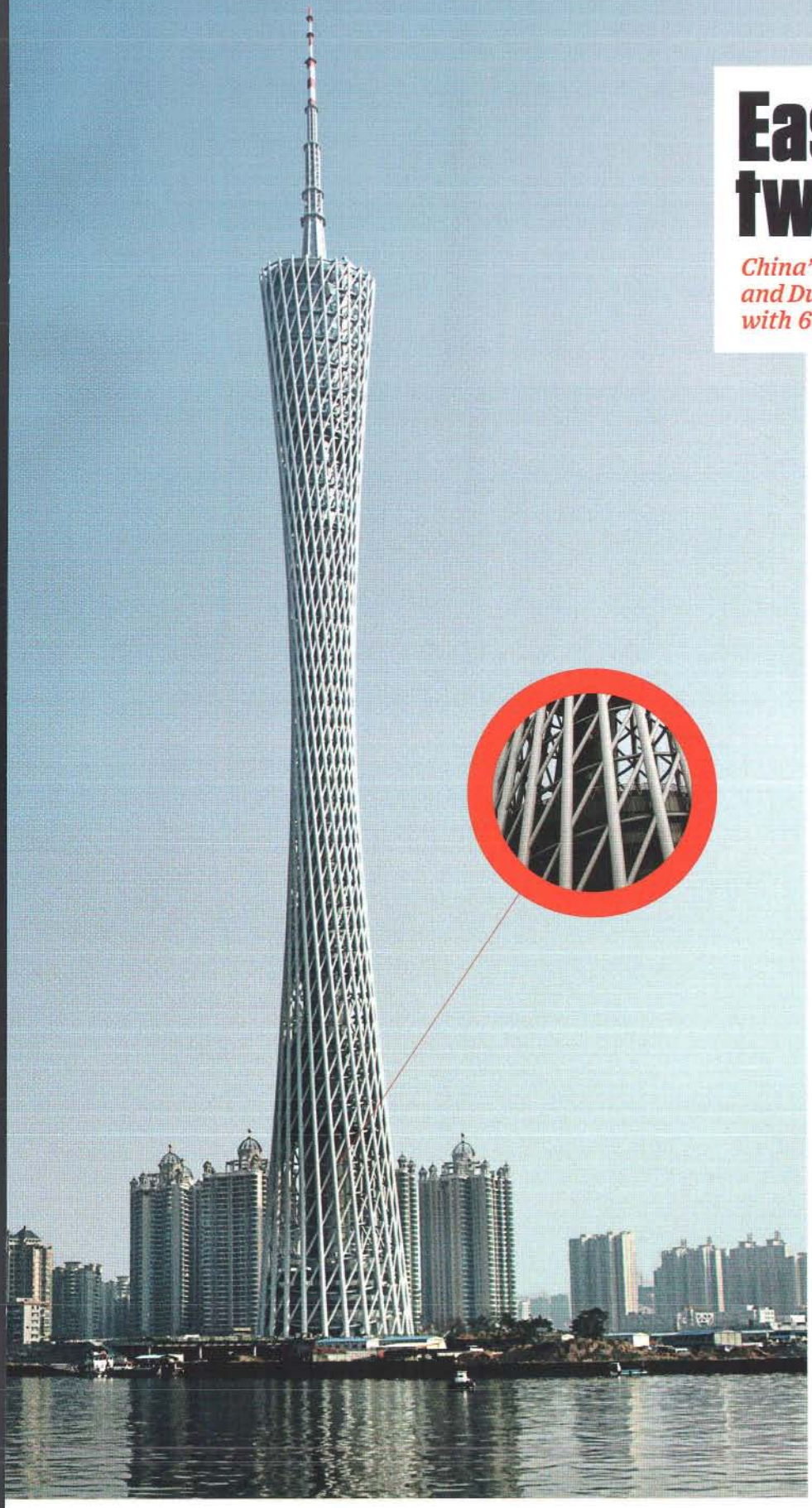
TOWERING FACTS

- At the waist of the building, a staircase wraps around the concrete core. Called "The Skywalk", it will take visitors from around 170m to 350m.
- **Engineers estimated that for every metre they narrowed the waist in modelling, around 3,000 tonnes of steel reinforcing would be required.**
- To keep the core as narrow as possible, space was saved by fitting double-decker lifts. Two separate staircases wrap around each other like a double-helix.
- **To prevent tall buildings from swaying, giant concrete blocks or steel pendulums known as tuned mass dampers are fitted. The Guangzhou TV Tower uses two giant water tanks on rollers that double as reserve supplies in case of fire.**
- State-of-the-art pumps were used to send self-compacting concrete to the top at 110km per hour to make the floors.
- **The tower's owners say it is topped with the world's highest Ferris wheel. The cars rotate around the inclined roof on a track.**
- Chefs won't serve soup in the restaurant on floors 84 and 85 as the liquid's movement reveals the slow sway of the building and makes diners queasy.

PHOTOGRAPHY: EVERETT; CORBIS. GLOBAL FILM GROSSES FROM IMDB.COM AND THE-NUMBERS.COM

East Asia's twisted tower

China's latest skyscraper is a British and Dutch collaboration – laced with 600 data-dripping sensors



At 610 metres, China's Guangzhou TV Tower is the third tallest freestanding structure in the world, due for completion this November. But the quest for a "sexy skyscraper" of such vertigo-inducing proportions posed Dutch husband-and-wife team Mark Hemel and Barbara Kuit of Information Based Architecture some serious challenges.

First, there's its geometrical complexity. The tower's giant steel lattice, formed by 24 columns and 46 rings, called for collaboration with Arup, the British engineering experts. Using Arup's parametric associative software, Hemel and Kuit generated a computer model of the building in its entirety, which allowed them to calculate how each new design decision affected the rest of the structure. The twisted shape of the tower means that each of the 1,104 joints in the lattice is similar, but not identical. Having a software render of each joint allowed them to be designed automatically and cheaply. Joop Paul of Arup describes the process as "mass customisation".

Another challenge was that columns starting on one side of the tower finish on the opposite side, which made it difficult to place them precisely. To calculate the exact positioning of the structural members, three GPS base-stations were installed around the tower to help with construction.

At such great heights, things risk getting a little... unstable. So during construction, 600 sensors were embedded into the concrete core and the steel columns that spiral around it. Named PolyU's Mega-Structure Diagnostic and Prognostic System, it documents the structural behaviour of the tower and feeds it to engineers at Hong Kong Polytechnic University. Not only does it allow early identification of structural deterioration, but, admits Hemel, the system is the building's "black box recorder", enabling "the assessment of structural safety immediately after unexpected disasters". Nice to know they're planning ahead. *hemel.dircon.co.uk* **Tim Abrahams**

YOUR INTIMATE-THEATRE DECISION TREE

Proscenium arches? So 2009. Technology has helped theatre evolve off the stage and on to the street, hiding drama in plain sight and making the audience part of the action through dialogue and directions issued via headphones. But which ones to participate in? Allow WIRED to help. **CB**

START

Are you too shy to join in the performance?

N / Y

The Invisible Show Actors on the street play out a series of emotionally intense scenarios. The public is oblivious, but headphone-wearers can hear the dialogue. *www.redshifttheatreco.uk*

The Bench A show for just two strangers sitting on a bench. Each listens to a separate audio track, which tells them what to say and do. *www.rotozaza.co.uk*

Would you prefer there to be no one watching?

Y / N

Do you enjoy hanging out in libraries?

N / Y

The Quiet Volume Taking cues from library cards, marginal notes and recorded whispers, the two participants play out a drama that reflects on the experience of being in a library. *anthampton.com*

Every Minute, Always Couples sit in a cinema, as moments from *Brief Encounter* are played on the screen. These functions as cues and mirrors for the headphone-based drama. *melaniewilson.org.uk*

Would you prefer a trip the cinema?

Y / N

Do you think flashmobs are passé?

N / Y

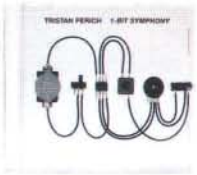
As If It Were The Last Time This "subtlemob" asks participants to perform otherwise unnoticeable actions (such as changing direction when you catch eyes with someone). *subtlemob.com*

When We Meet Again Video goggles replace your vision with someone else's, and recorded audio tells you where to look. This creates a "body swapping" experience. *meandthemachine.co.uk*

Do you want more than just headphone-theatre?

Y / N

Then start again...



THE 'LIVE' ORCHESTRA IN A BOX

1-Bit Symphony might be packaged like a CD, but according to its composer, Tristan Perich, it isn't a recording – it's a performance. Inside the jewel case lies a microchip that plays a five-movement symphony with "a very dense, cascading, raw digital sound". Comprising a battery, on/off switch, skip button, volume control and headphone jack, the circuit is also its own cover art.

Although Perich wrote out the music traditionally, the chip's 8kB memory was not large enough to store it. So he translated it into low-level assembly code and compressed the piece into a set of melody loops organised by cues. "It's like repeat signs in a musical score," says the 28-year-old New Yorker. "Which is also like a programming language."

The project's minimalism was inspired by science. "In theoretical physics you have a few elementary particles and forces that interact in very complex ways to create the world around us. The idea of simplicity at the core of a sophisticated system is very beautiful." That's why, he says, *1-Bit Symphony* is best heard in its most basic form, "live" from the chip, rather than on a computer in higher-bit audio. Take that, file-sharing. **CB**

Out August 24, 1bitsymphony.com

PHOTOGRAPHY: NICK WILSON

Tunes on the brain

One artist is creating music from brainwaves – so are EEG machines the new Auto-Tune?

Luciana Haill wants to peer inside your mind – but don't worry, it's all in the name of art. In her "neurofeedback" performances, the 37-year-old from East Sussex uses electroencephalography (EEG) to detect her (or a volunteer's) brain activity. Her computer then visualises the data as an undulating digital landscape (*see left*) and projects it on to a big screen. At the same time, another program turns it into music, with certain sounds activated by particular wave frequencies.

"The left and right sides of the brain can independently control eight different tracks," she says. "It evokes a mysterious atmosphere when you first hear sounds being triggered and controlled by someone's brain. Initially I'll be using another EEG to drive it myself, but once they're settled in they'll experience their own brain waves being sonified."

And it's not just music: recently Haill has used EEG to live-edit video. "If someone's producing a lot of beta waves then that's quite fast activity – that would be like the fast-forward. If they slow down into alpha waves, the edge of concentration and relaxation, it will start to pull the film backwards."

Having become fascinated with brain scans as a teenager while being treated for meningitis, she read about EEG in a 1993 issue of WIRED US. That year she was studying interactive art at the University of Wales under tech/cyber-art pioneer Roy Ascott, and decided to use EEGs in her work. But until as late as 2008 many people suspected that her routine was hokum. "Some imagined I was a choreographed smoke-and-mirrors act, so I'd hang around afterwards so they could speak to me," she says. "I used to get it a lot, but now there is greater discussion of brain-computer interfaces in the media." See her perform at the Phoenix, Brighton, in September. Listen to her headmusic at *wired.co.uk/brain* **CB**

PLAYLIST

CULTURAL PICKS OF THE MONTH 09.10

01

RE-CREATION

Inherited a late aunt's gruesome coffee table? Nikola Nikolov of Studio-Re-Creation, based in Wormerveer in The Netherlands, can turn it into something more stylish. This cool robot used to be Nikolov's first car, a Lada Samara Diva. *studio-re-creation.com*

02

DARWIN CHAIR

From the mind of cult graphic designer Stefan Sagmeister comes the Darwin chair. It has 200 sheets of paper instead of cushions or fabric. Each "page" is printed with a different pattern or colour, so when you fancy a change, just flip or tear. Cosy. *droog.com*

03

ALT/1977

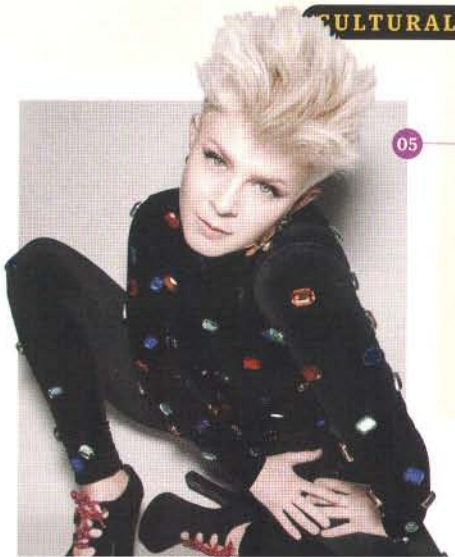
Time travel rocks, but if you jump back to 1977 the demure lines of your iPod could blow your cover. In his ALT/1977 series, San Francisco-based artist Alex Varanese reimagines today's tech as it might have been then, in a set of just-believable-enough print ads. *alexvaranese.com*

04

SKOOG

This colourful cube is a musical instrument. Designed Ben Schögler and David Skulina of the University of Edinburgh, it is intended to bring music-making to people of any ability – or disability. Squeeze, pinch or twist it to make a tune. *£500 skoogmusic.com*

05



ROBYN

The Swedish electro-pop singer returns with the next instalment in her *Body Talk* album trilogy. Catch her confessional lyrics and synth-driven songs when she tours the UK in October. *Body Talk Part 2* is out September 6. For tour dates, visit *robyn.com/tickets*

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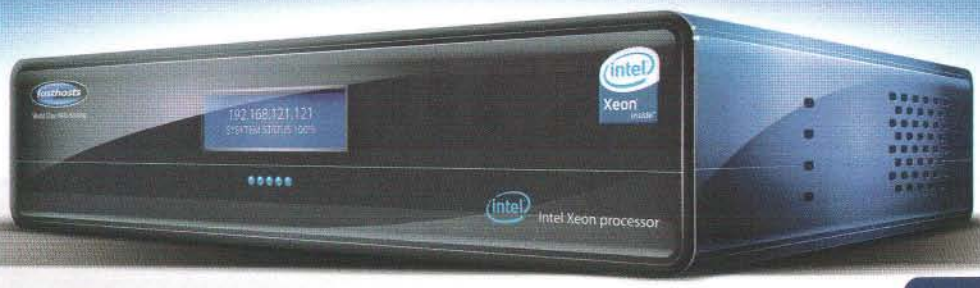

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Fetish

This month: a hybrid bike, a spidery PC case and a stealthy bow **PLUS:** hydrogen-powered car kits and low-energy lighting

OBJECTS OF DESIRE 09.10

A bicycle based on a luxury car

1

Lexus Hybrid bike
The Japanese car giant's first two-wheeler adopts tech found in its vehicles. Pedalling is boosted by a 240W electric motor and kinetic energy is recovered when braking to help charge the 25.9V battery. The lightweight frame is all carbon fibre and the eight-speed Shimano gear system is electric. *Prototype only. lexus.co.uk*

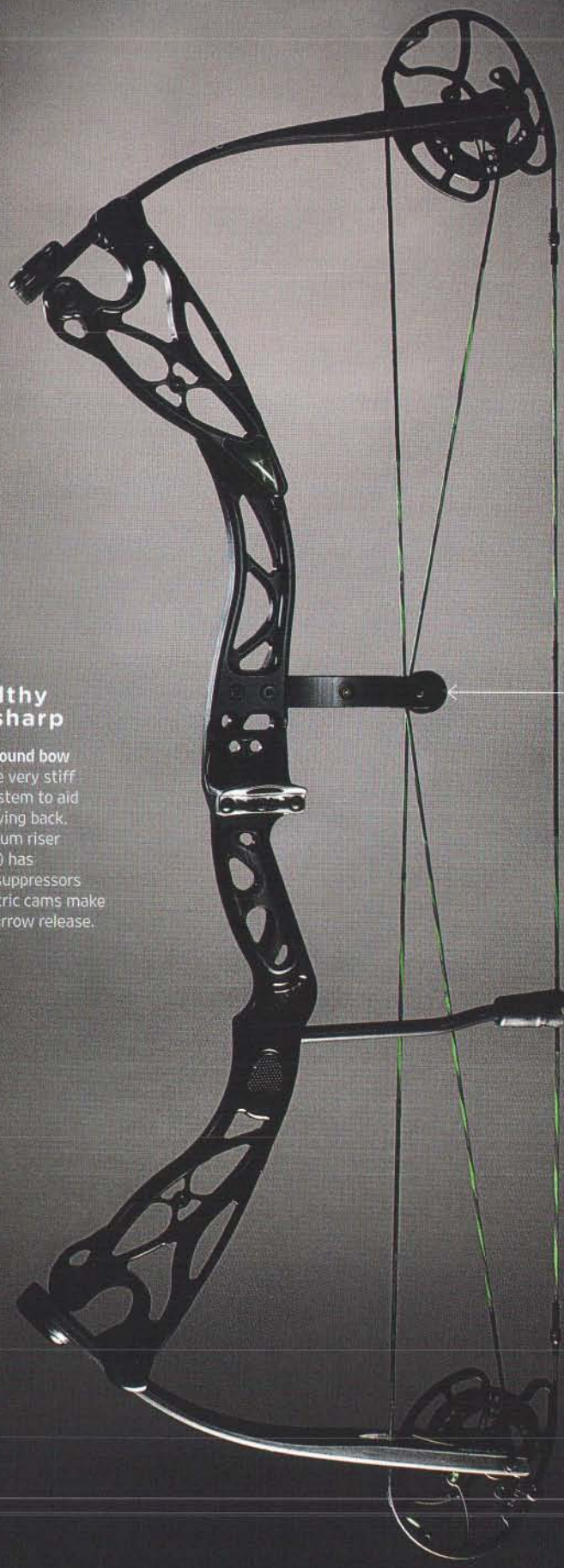
The electric gear transmission is based on that of the Lexus LS 600h limousine

PHOTOGRAPHY: OWEN SILVERWOOD

A PC test station inspired by spiders

2

Lian Li PC-T1R Spider test bench
It looks like a scary robot spider – but the PC-T1R is designed to make it easy to swap test components in and out of a PC chassis. The abdomen holds an ATX power supply, and the head takes a slim optical drive, 3.5" desktop hard disk and a mini-ITX motherboard.
£100 lian-li.com

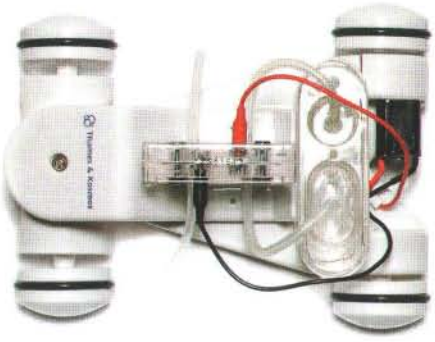


Silent, stealthy and arrow-sharp

Rytera Alien-X compound bow
Compound bows have very stiff limbs and a pulley system to aid the archer when drawing back. The Alien-X's aluminium riser (the body of the bow) has integrated vibration suppressors and the twin symmetric cams make for a smooth, silent arrow release.
£500 bowsports.com

The bow exerts 686 N (70kg) of resistance. The arrows fly at 100 metres per second

PHOTOGRAPHY: OWEN SILVERWOOD



Show off your fuel cell

1

Thames & Kosmos Fuel Cell 10 car
This clever car kit is a showcase for hydrogen fuel-cell tech – the display stand doubles as a rolling road if you don't want the vehicle running under people's feet. It also comes with a multimeter to gauge your cell's efficiency. *£109 www.scienceshop.com*

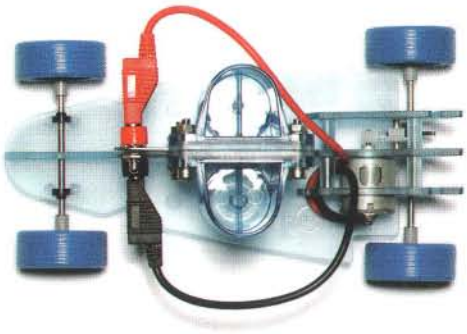
Remote-controlled and water-powered

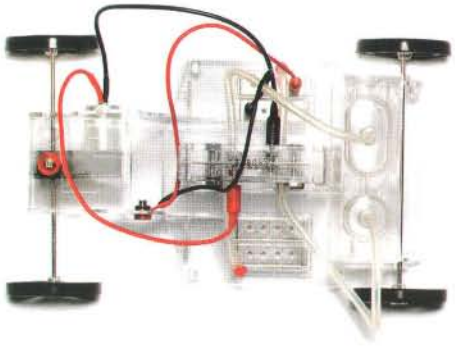
2

Horizon H-Racer 2.0
Unlike the other kits, the H-Racer has a separate filling station. This extracts hydrogen from distilled water via electrolysis, which you pump into the car's inflatable hydrogen tank. It runs for up to five minutes, and has a remote infrared steering control. *£90 arcolaenergy.com*

H to go

Hydrogen-powered cars you can build and race





On-board power generation

3

Heliocentris Dr FuelCell car
A self-contained hydrogen fuel-cell car. The on-board module separates hydrogen from water using power from a five-cell photovoltaic panel. The same module then acts as a fuel cell, converting the hydrogen into electrical energy to power the car. *€195 heliocentris.com*

A transparent and speedy racer

4

Thames & Kosmos Fuel Cell X7
More than any of the kits, the X7's clear design lets you see electrolysis in action – the water level slowly decreases as oxygen bubbles off and hydrogen is collected, before the fuel cell reverses the process to make electricity. It's also the fastest small car here. *$150 hammacher.com*

PHOTOGRAPHY: WILSON HENNESSY, DAVE LIDWELL

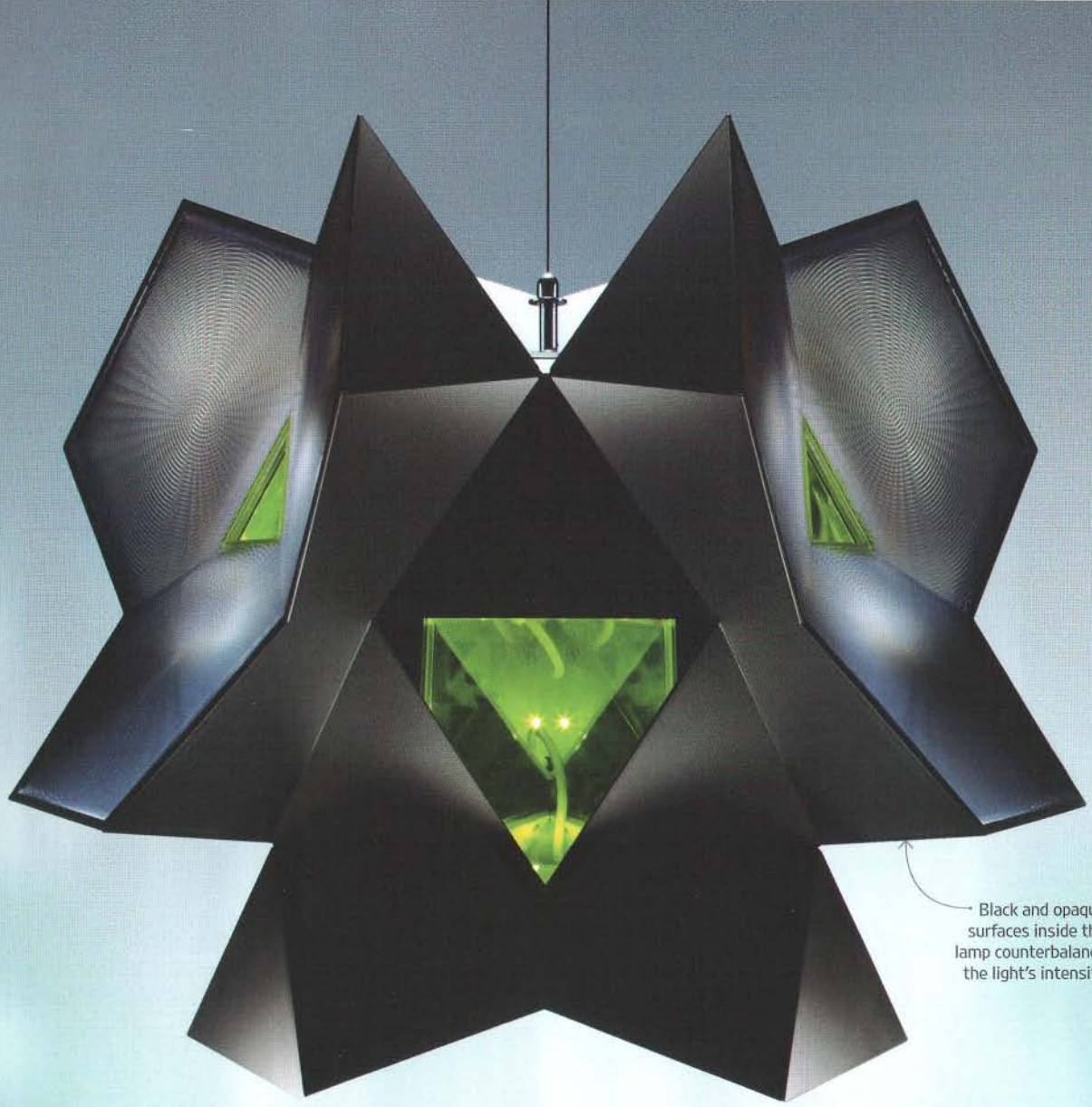
Zero-emission RC racing

5

Horizon H-Cell 2.0 RC kit

Horizon's RC kit is an electric/hydrogen hybrid, designed to fit in a Tamiya radio-controlled car chassis. The hydrogen refuelling station stores the gas in HydroSTIK canisters, each holding 15 litres of H (or 12Wh of energy). *£500 (fuel-cell kit) £1,350 (assembled car) arcolaenergy.com*

The on-board battery boosts the motor's acceleration. The car can cruise at 35kph

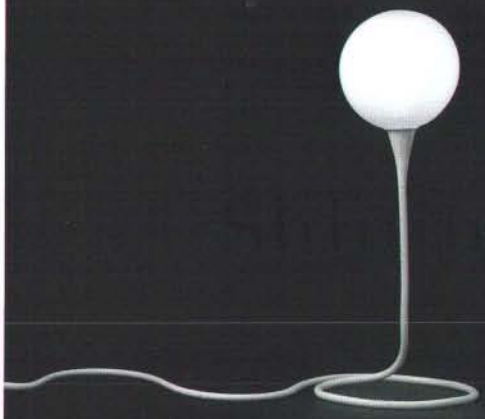


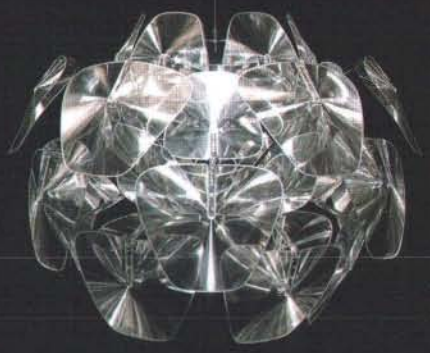
Black and opaque surfaces inside the lamp counterbalance the light's intensity

The dimmable, expandable star

Zumtobel Starbrick

The light from this star-shaped lamp can be focused to a spot or diffused. Starbricks can be hung from the ceiling or stacked into floor-lamps – but why stop there? Its designer, Olafur Eliasson, claims you could build a light-up house out of them. *€3,000 (each) starbrick.info*





2 An illuminated balloon

PEGA D&E Blo Light

As you pump the Blo Light's switch, its latex balloon inflates and illuminates. A pressure sensor raises the brightness as you pump, and releasing the pressure valve dims it. The playful design is intended to help you appreciate the energy you're using. *£TBA www.pegadesign.com*

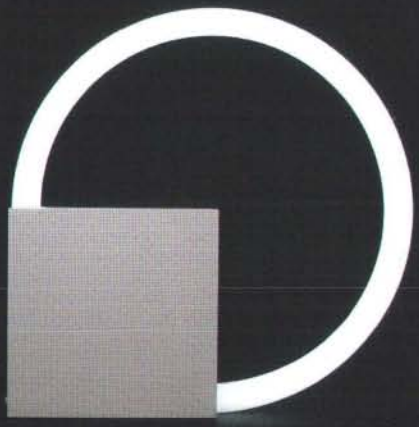
3 Diamond-inspired, low-energy sparkle

Luceplan Hope

This modern chandelier uses polycarbonate lenses to multiply the light and maximise the illumination of its low-energy 23W bulb. Each lens is imprinted with microprisms, so they sparkle like the facets of the Hope diamond – hence the name. *£795 luceplan.com*

Shining lights

Beautiful illumination that doesn't waste energy



4 High-efficiency minimalism

Boops Cirkellamp

Designed in 1968 by Aldo Van den Nieuwelaar, the minimalist Cirkellamp has been brought up to date with a modern CFL bulb and an efficient pulse dimmer to adjust brightness and save energy. The manufacturer claims the bulb will last 16,000 hours. *€595 www.boops.nl*

5 A lamp that runs on recharged batteries

Sanyo ENL-Y1S Eneloop lamp

Sanyo's Eneloop range showcases its rechargeable batteries – this lamp provides up to 45 hours of continuous white light (or 16 hours of blue "healing" light) from two Eneloop AA batteries. And if you pick up the lamp it can be used like a torch. *$210 sanyo.com/eneloop*

PHOTOGRAPHY: WILSON HENNESSY, DAVE LIDWELL

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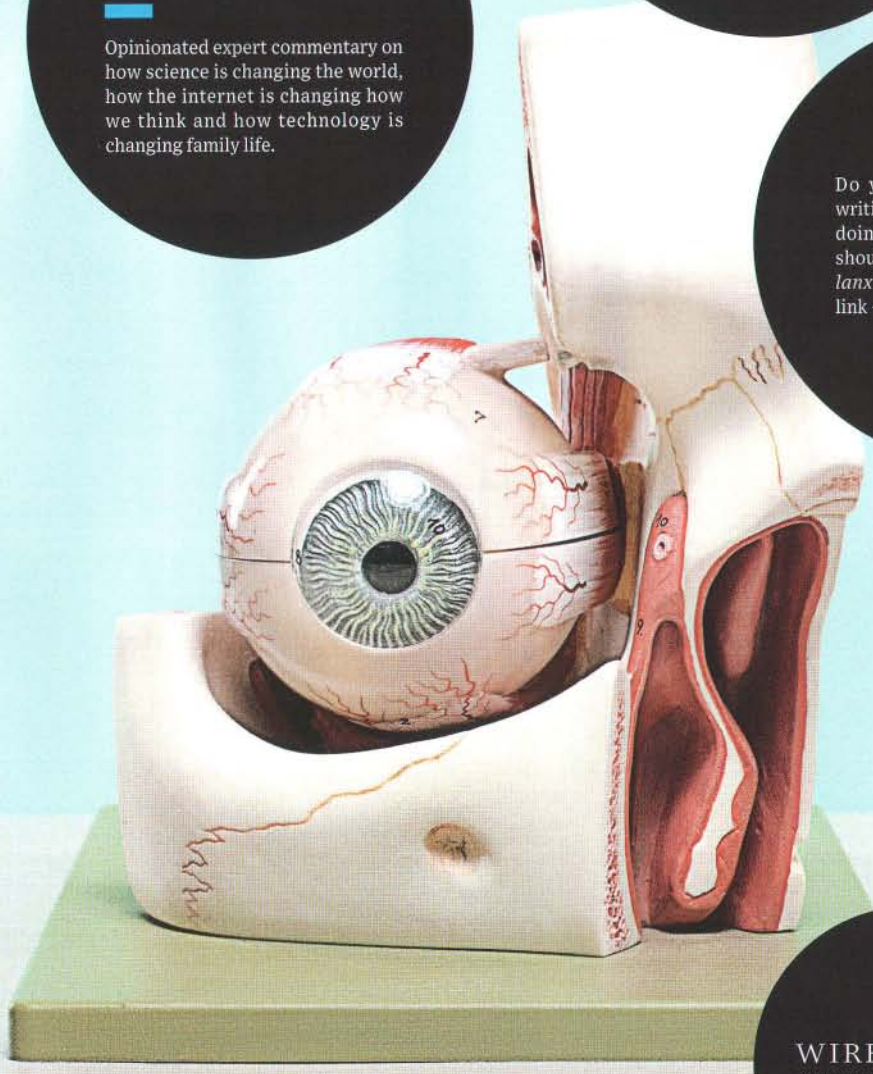
Do you think you should be writing for wired.co.uk, or are you doing something online that we should know about? Email *nate.lanxon@condenast*.co.uk with a link – we'd love to hear from you.



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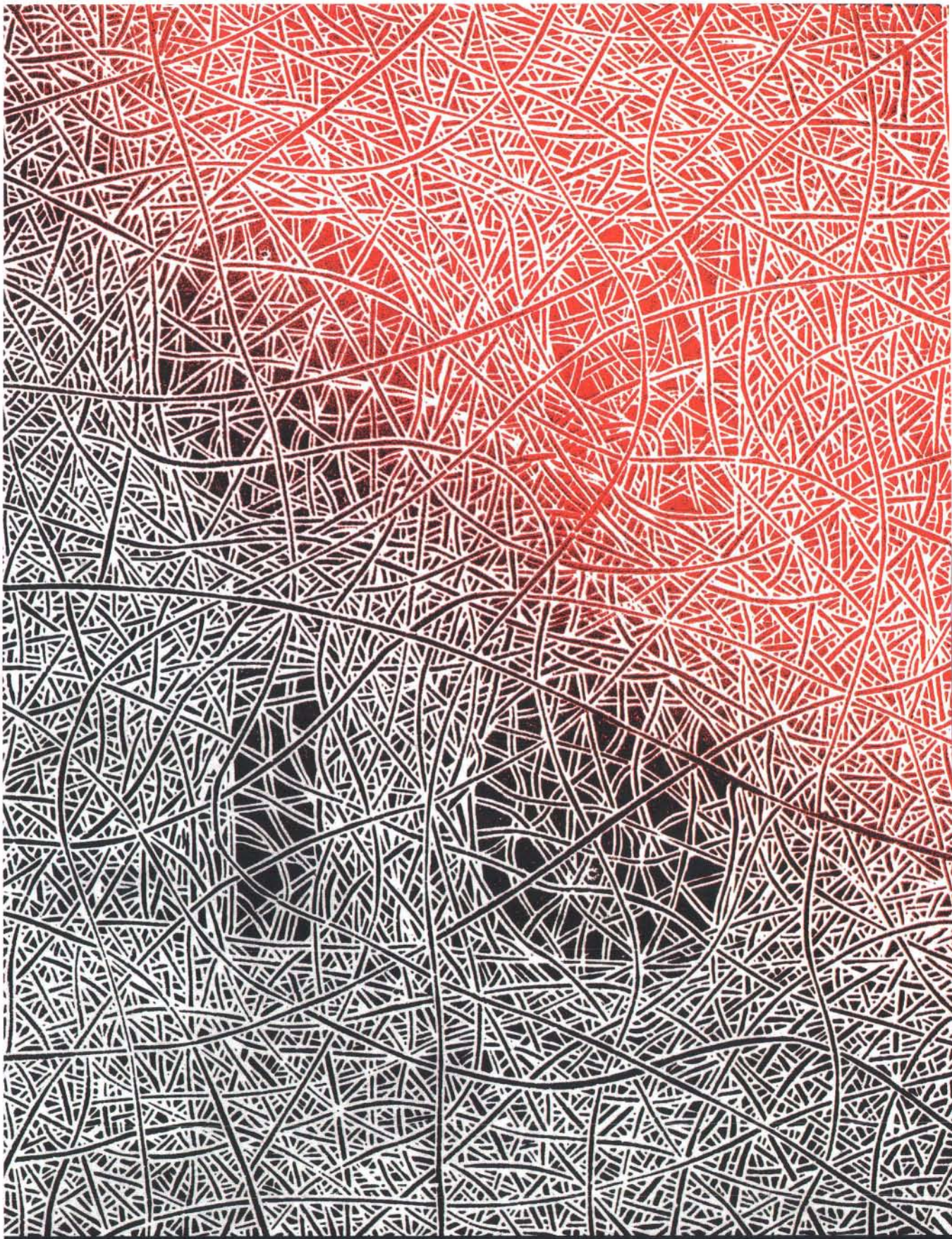


ILLUSTRATION: MARK ANDREW WEBBER.

FEATURES /09.10

WARNING! TUCKER FILTH AHEAD

SURVIVE A NEW REGIME

When BBC2's *The Thick of It* won three Baftas, the show's creator, Armando Iannucci, thanked Lib Dem leader Nick Clegg "for destroying our plans for the next series". So how will spin doctor Malcolm Tucker (Peter Capaldi) and special adviser Ollie Reeder (Chris Addison) cope in the cold? Tucker offers WIRED an exclusive insight.

1 I'M TOO GOOD FOR THEM ANYWAY

"Kiss my decomposing arse and wake up and smell the cock. There's no room for talent like Tucker in this coalition of people who weren't quite good enough to win. It's like Tim Henman watching Eddie the Eagle on Betamax video."

2 STICK THE KNIFE IN

"It's a Push-Me-Pull-You with no heads and two arseholes. Three cheers for the tiny-cocked no-chin old ruling class getting back in. It means you get far more women in the Cabinet, because those fuckers bring their nannies with them."

3 BITE THE HAND

"But why should I tell a Condé Nast magazine my plans? You're all shallow, venal, self-serving fuckpumps with a farcically inflated sense of your own importance. You're so far up yourselves you've punctured your kidneys."

4 WIDEN YOUR TARGET

"Still, you're not as bad as those twats on Twitter. They look like they've survived in a cellar on a diet of KFC and biscuits for the last 20 years. They haven't, of course. Nearly all of them are waddling cockstumps based in their sodding bedrooms."

085

THE HOW TO ISSUE

GUEST-STARRING
THE THICK OF IT'S
MALCOLM TUCKER
(PETER CAPALDI)
AND OLLIE REEDER
(CHRIS ADDISON)
PHOTOGRAPHY:
JAMES DAY

CONTROL THE AGENDA IN A MEETING

Gavin Davis is a director at Pelham Bell Pottinger, the financial and corporate-communications agency. Here are his top tips for getting your own way, face to face.

1 **GET THERE EARLY**

Davis is amazed how often people leave tasks such as printing their presentation and planning transport to the last minute. "Being early gives you time to collect your thoughts and be ready. If you're late, you're already on the back foot."

2 **FIND SOME COMMON GROUND**

Try to break down barriers – maybe by chatting about sport or a movie. If there's a formal meeting, have an informal gathering first to discuss objectives and make a connection, "and see the colour of each other's eyes".

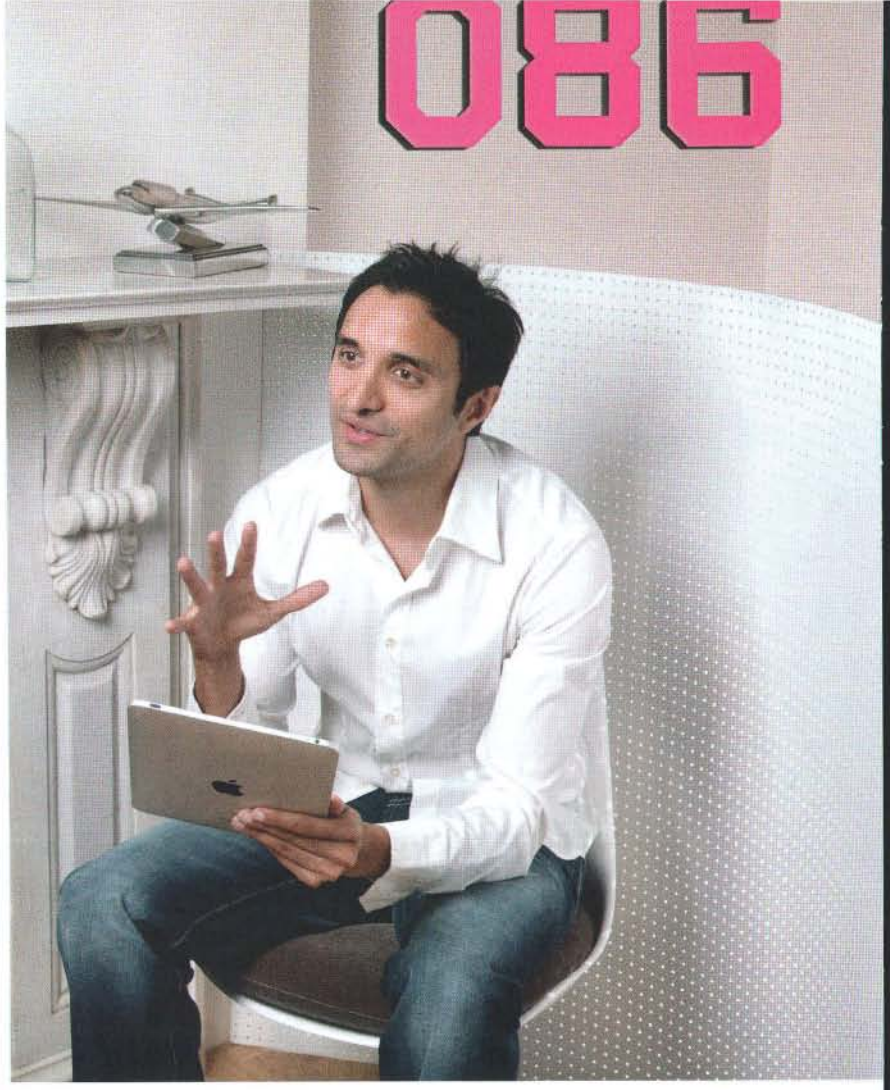
3 **GET IN EARLY ON THE DISCUSSION**

This shows you're engaged. "It's amazing how people will direct the conversation to those they think are engaged. If you leave it too late to make your point, everyone will expect something groundbreaking."

4 **THINK ABOUT SEATING ARRANGEMENTS**

If you're trying to win new business, make it friendly and relatively informal, says Davis. But if you're in negotiations, draw battle lines and face them from the other end of the table: "You need to take a position."

Chris Finnamore



MAKE MONEY FROM THE IPAD

Missed out on the first App Store gold rush? Never fear: the iPad offers app developers even more chances to make their fortunes. Ajaz Ahmed is chairman of AKQA, a multi-award-winning agency that has created iPad apps for Nike and Gap. He is also the executive producer of Jamie Oliver's bestselling iPhone app, *20 Minute Meals*. Here, he explains what makes the perfect iPad app.

1 **WAIT**

"With *20 Minute Meals*, we learnt the benefit of 'late-mover advantage'," Ahmed says. "We looked at what was out there and how to improve it before starting. The better (not the earlier) products go on to be more popular."

2 **PICK A CATEGORY**

"Games and entertainment tend to top the charts and are competitive, though the App Store is a level playing field. The iPhone racing game we made for Volkswagen had six million downloads, but education can also be lucrative."

3 **PLAY TO THE IPAD'S STRENGTHS**

Design your app specifically for the iPad. "This means using an intuitive interface. Focus on making your app work fast and elegantly. Don't retrofit an old design: it won't be as good and the user will notice."

4 KEEP THINGS SIMPLE

Don't introduce layers of complexity by adding features that aren't important to users. "Cramming in too many features is the biggest mistake developers make because they think the more features, the more popular the app will be. In fact, the opposite is true: the best and most successful apps do one job tremendously well."

5 KEEP YOUR TEAM SMALL

"As long as you've got good people, the smaller the team, the better the product." You will need an editor-in-chief or an app director. "The flakiest apps are the ones that are produced by committee where everyone is nice to everyone else and people are just putting new features in for the sake of it."

6 DON'T ANNOY APPLE

"Don't try to recreate aspects of an iPad. For example, don't replace the iPad home screen with a new desktop." Apple approves 95 per cent of apps within a week. Study the developer rules at *developer.apple.com/ipad/sdk/*

7 MAKE SURE THAT THE PRICE IS RIGHT

"Pricing depends on perceived value. The highest-grossing apps do not always charge the highest fees, but they have captured the imagination. Where an app is free and provides a good service, advertising is justifiable. Apps that carry ads that only add clutter reduce the value."

8 DON'T STOP AFTER DEVELOPMENT

All apps have a natural lifecycle, so you should expect to see some drop-off. But you can keep yours in the charts for longer by updating it or reducing the price. "But it's most important to create work that will inspire: Apple will promote apps that have universal appeal through its advertising campaigns, iTunes and the App Store. And, when a developer creates something incredible for a new device, you can't overestimate the amount of coverage it will get."
Mic Wright

PHOTOGRAPHY: MICHAEL PILKINGTON. ILLUSTRATIONS: JEZ BURROWS; JOE SNOW

GET IN THE ZONE

Top athletes often speak of the "zone", a mental state that promotes peak performance. According to sports psychologist Michael Lardon, author of *Finding Your Zone*, being in this state means your mind is totally absorbed by the task in hand. Thought and action are in perfect sync, and the experience of time slows down. Here's how to get there.

1/ **Peak performance requires foresight. Prepare for as long as possible. "There is a relationship between preparation and anxiety," Lardon says. "The more prepared you are, the fewer situations you have to deal with."**

2/ In philosophy, solipsism states that reality exists only within your mind. Hone this mindset to your advantage: practise simple tasks that are mentally or physically uncomfortable, or even painful, to optimise your endurance.

3/ **Have a simple plan and stick to it. According to Lardon, athletes choke when they second-guess themselves and doubt intuition. Remember the Zen saying: "Those who think do not know; those who know do not think."**

4/ Results are, paradoxically, better when you stop worrying about them. "A lot of people get lost in a sea of amorphous goals," Lardon says. "Goals need to be achievable and accountable."

5/ **If your motivation for doing something is extrinsic – fame, say – then forget about the zone. "When we seek approval, we set ourselves to be at the beck and call of too many masters," Lardon says.**

6/ Master your fears by getting used to them, and by seeing the big picture. Remember: at least five billion people couldn't care less about the outcome of your performance.
João Medeiros

CREATE NEW LIFE

It doesn't take a genius to create a new life. But creating a synthetic organism – now that's difficult. According to Craig Venter – the American biologist and author of "Creation of a bacterial cell controlled by a chemically sythesised genome" (*Science*, May 2010) – all you need is a DNA synthesiser, chemicals, an empty cell and some genetic code. Oh, and $40 million of investment.

1 DESIGN A BLUEPRINT

Write code, or genetic software as Venter calls it, describing the genome of an existing organism and modify it by removing certain genes that won't compromise its ability to survive, while inserting new synthetic genes that don't exist in nature. "Life is basically a result of an information process, a software process," Venter told *Science*.

2 CREATE THE HARDWARE

You can make DNA using the chemicals (nucleoside phosphoramidites, the basic constituents used to make the oligonucleotide building blocks of base pairs) and a DNA synthesiser. These short chunks have to be stitched together in the right order to recreate the million-plus letters that make up the genome. Venter claims it's like assembling Lego.

3 BOOT IT UP

Take a cell of a closely related bacteria, and remove its nucleus so it contains none of its original genetic material. Then transplant your synthetic genome into the host cytoplasm. Once inserted, chemical markers added to the genome, called methyl groups, trick the cell into disabling defensive enzymes that could potentially destroy it.

4 RUN IT

The cell instantly starts reading the new software and begins making a different set of proteins. According to Venter, "All the characteristics of the first species disappear and a new one emerges." The cell starts to divide over and over, creating more synthetic versions. Congratulations – you're a parent.
Duncan Graham-Rowe

BUILD A DRONE

Chris Anderson, editor in chief of WIRED US, founded DIY Drones.com, a community of amateurs who build unmanned aerial vehicles (UAVs). Plus, he set up WIRED's GeekDad blog, and wrote the foreword to the new *Geek Dad* book (Gotham). Here he explains how to join the model-aircraft revolution.

What was once a noisy, dangerous, difficult and expensive gas-powered hobby (remember those weeks of gluing balsa only to see it all shatter on launch?) has been transformed by the arrival of powerful brushless electric motors, lithium-polymer batteries and programmable digital radios, to say nothing of awesome, cheap premade planes from China. They're now quiet, safe and easy to make.

Only one problem: they're still as hard to fly as ever. The weak link in the chain is still you. But in the full-size aviation business, there's also been a revolution, and that's to take people out of the cockpit. The rise of UAVs is the biggest story in aerospace. Pilotless drones can soar for days; ground controllers often "fly" only the onboard cameras, treating the drones as airborne video platforms requiring no more piloting skill than an Xbox 360 game.

Good news: now you can do the same. The sensors, processors and wireless modules that drive the autopilots of military drones are today found in similar form in a smartphone. The tech that steers cruise missiles powers a Wii controller. DIY Drones is all about using this generation of cheap electronics to turn model planes into UAVs: they fly by themselves, following GPS waypoints to complete missions and send back video in real time.

1 HERE'S HOW TO GIVE YOUR PLANE A BRAIN: START WITH A CHEAP, FOAM, ELECTRIC RC PLANE

We like the Multiplex EasyStar, but a cheaper option is the Dynam Hawk Sky. Any RC gear with five channels or more is fine. Once you've got the hang of it, you can upgrade to planes that can carry bigger cameras and have a range measured in tens of kilometres (but remember: it's illegal to fly out of line-of-sight and above 120 metres in most countries without regulatory approval). You'll probably want to get an onboard video camera and wireless link, too. There are a lot of sources for these, which are used by the fast-growing FPV (first-person view) RC community. Google around to see the range of choices.

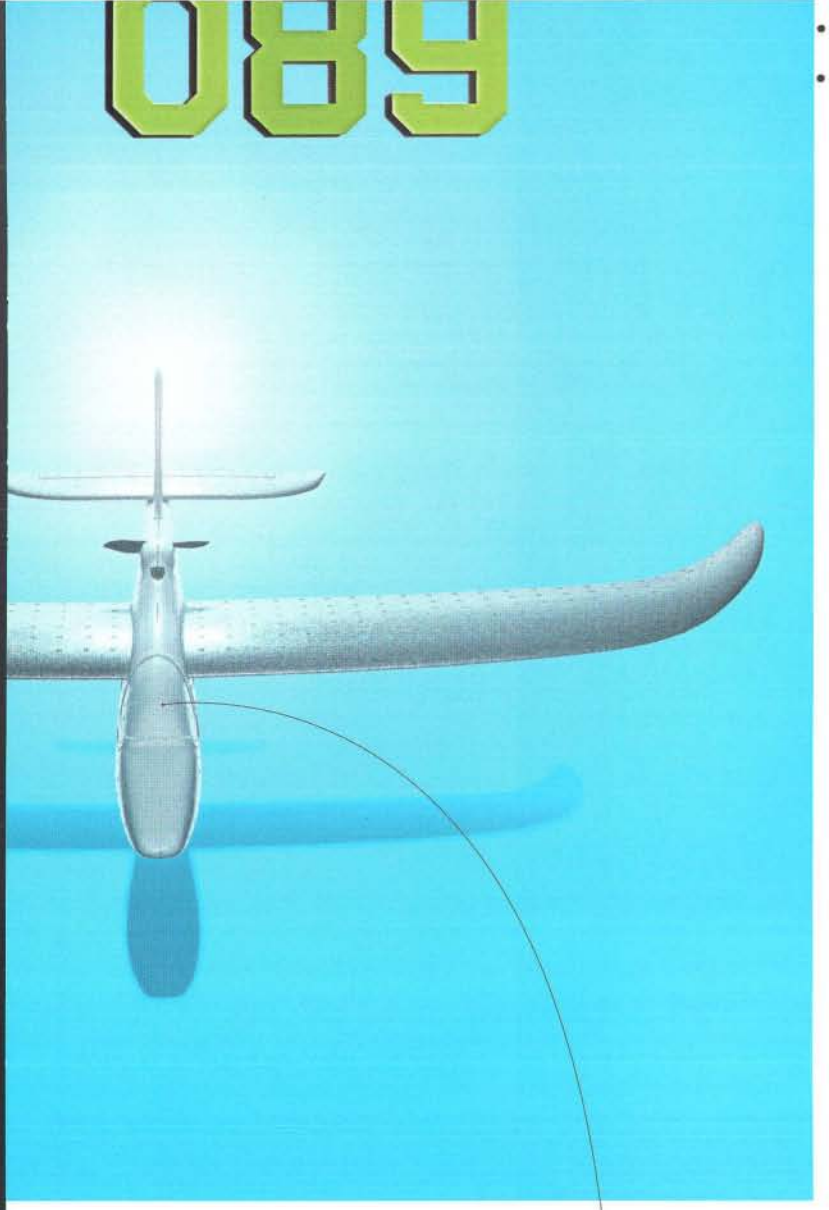
2 GET AN AUTOPILOT

You can buy autopilots that range from $700 to $5,000 – we like the AttoPilot line. Or you can buy an open-source autopilot and, with assembly, get a sophisticated UAV control system for $300. The father of open-source autopilots is called Paparazzi and works only on Linux. Our community developed an easier-to-use autopilot, called ArduPilot, which is based on the popular Arduino platform. The newest version, ArduPilot Mega, uses state-of-the-art gyros, accelerometers, GPS and pressure sensors to provide a complete UAV control system, including ground station, camera controls and datalogging.

3 PLAN A MISSION

Once you've put the autopilot in the RC plane and configured it properly, you now have the ability to switch to autonomous control any time you want (or just tell the plane – now a real UAV – to take off and land by itself). You'll probably want to do a few test flights, taking off manually and checking the autopilot is doing its job by having it return home on its own. But after that you can use the desktop ground station to point-and-click GPS waypoints on Google Maps. Tell the UAV where to go and what to do at each waypoint ("loiter", take pics or just move on). The software is smart enough to adjust the altitude to follow the terrain.

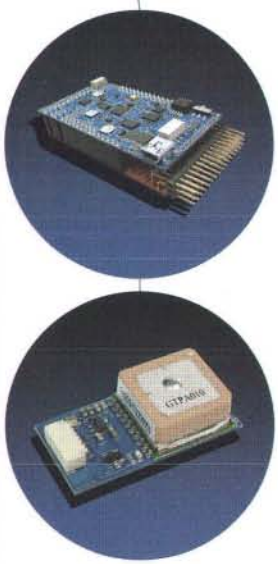
PHOTOGRAPHY: WILSON HENNESSY. ILLUSTRATION: JEZ BURROWS



4 LAUNCH

Off it goes – by itself! Watch the progress on the ground station, with the plane icon moving on a Google Earth map, the telemetry displaying what's happening onboard in a virtual cockpit view and real-time video showing the ground below your UAV. Marvel at the quality of modern consumer video and radio equipment, which can give a better picture than those UAV videos from Iraq. Consider the future of aviation. If you can do this with parts costing a few hundred pounds, how soon until the skies are dark with robotic planes?

Chris Anderson



A 3D rendering (*upper inset*) of the ArduPilot Mega and the IMU shield, by Sandro Benigno; the GPS unit (*below*)

WRITE AN E-BOOK BESTSELLER

By day, Stephanie Chandler is CEO of the California company Authority Publishing. By night, she runs an e-book empire with five-figure revenues, which includes the bestseller *From Entrepreneur to Infopreneur: Make Money with Books, e-Books and Information Products*. Envious of her second income? Here's her guide to how you can get one too.

1 CHOOSE A SUBJECT

"The key is that it must solve a problem by teaching you how to do something," says 37-year-old Chandler. "You really have to think about marketing from the get-go: make sure the subject matter hasn't been overdone and make sure that there's a need for a book on the topic you're planning."

2 ESTABLISH YOUR AUTHORIAL CREDENTIALS

"This is very important. A lot of writers open their e-books with an introduction letter, and that's a great place to mention your experience and why you wrote this book – play up your biography as much as you can with any related experience. And include a photo."

3 MAKE IT EASY TO READ

"You want to keep in mind that most people don't read nonfiction books from beginning to end – they jump around – so make it easy for them to find information. If you have any key points you want to make, do so at the beginning. And you want a table of contents. Text should be 14-point, in a clear typeface."

4 GET MARKETING

"Consider the search engines: how do you want your book to show up? You can accomplish that in the main title – which is better off being practical rather than catchy – or in the subtitle. Create a site with good sales copy: outline the benefits the reader will get. Include testimonials and give-away pages."

5 TECHNICAL LOGISTICS

"For selling e-books through my own website I use a shopping-cart system, such as Payloadz.com or Ejunkie.com. I also use Smashwords.com for distribution – you submit your manuscript and it converts it into ten different formats and distributes it to various e-book outlets."

Charlie Burton

HACK CHEAP AIR FARES

Even without an ash cloud, air fares can be exorbitant. Chris Guillebeau, author of the forthcoming book *The Art Of Non-Conformity: Unconventional Strategies For Life, Work And Travel* (December 16, Perigee), is aiming to visit every country in the world by 2013. He gives his travel-hacking tips.

LOOK BEYOND EASYJET

Flying with obscure national carriers (eg Air Moldova) can yield bargains.

TRACK PRICES

Farecast and Yapta.com track airfares and predict whether the price will change.

EXPLOIT AIR MILES

US airlines are notoriously bad – but they have the most generous mileage programmes. So, even for Europeans, it's often more advantageous to join AA's club than BA's.

GO ROUND THE WORLD

Round-the-world tickets offer good value and flexibility. The key is to optimise the ticket. On segment-based tickets, don't have too many short-haul flights – take the Eurostar to Paris and save the RTW segments for going further afield.

Tom Cheshire

BUILD YOUR OWN SUPERCAR

You don't need to buy an Aston V12 Vantage or a Lamborghini to experience supercar performance (or just show off to the neighbours). The thrills of the boy- (or girl-) racer can be yours at a knockdown price – as long as you're ready to build it yourself. Here are three varieties of supercar kit that you can build reasonably easily in your garage.

1 THE FASTEST

The Ultima GTR

From £35,000

The base 300bhp engine will get you to 60mph in four seconds and up to 180mph. Ultima says you need around £200-worth of tools, but enthusiasts' build sites such as ultimagtr640.com say that you'll need £600. You'll require a garage but no prior build experience. *ultimasports.co.uk*

2 THE EASIEST TO BUILD

The Caterham

From £13,000

The dashboard and wiring loom are fitted; there are no metal panels to cut to fit and no welding. Described as a "big boys' Meccano set", its options range from the 105bhp Classic (£13,300) to the lightweight Superlight R500 (£40,200). *www.caterham.co.uk*

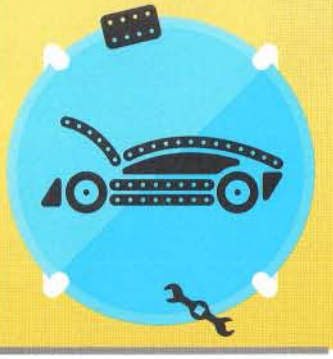
3 DO-IT-YOURSELF

The Haynes Roadster

Around £5,000

If you're technically proficient, you can build from scratch using a donor car with the help of Haynes's *Build Your Own Sports Car On A Budget*. This book shows you how to build a Lotus 7-style car, using a Ford Sierra and spending about £5,000. There are also build diaries online. *www.haynes.co.uk*

Chris Finnamore



READ SOMEONE'S MIND

In Marc Salem's presence, your thoughts are about as safe as personal data on a government memory-stick. His mentalism act, Mind Games, has delighted and spooked audiences from New York's Broadway to the Sydney Opera House, and Singapore's Esplanade to the Edinburgh Festival. Salem's skills didn't come easy: the 58-year-old magician spent 20 years studying psychology and "non-verbal communication". But, he tells WIRED from his home in New York, there are some mind tricks that you don't need to be an expert to perform.

EFFECT: A volunteer holds a £1 coin in one hand and a £5 note in the other. You can tell which amount is in which hand – even over the phone.

METHOD: "It's one of the few mentalism effects that really bases itself on thinking process and time delay," says Salem.

Ask your subject to put the note in one hand and the coin in the other, without your seeing. Tell them to multiply the amount in their left hand by 13 and indicate when they have done so, but not reveal the answer. Ask them to multiply the amount in their right hand by ten. Again, they're not to tell you the answer. If they paused for much longer when multiplying by 13, then the left hand holds the £5 note. Now ask them to add the results together in their head and concentrate hard on the sum – misdirecting them from the real giveaway. Reveal which hand holds what.

FOLLOW-UP EFFECT: If you're doing it in person, they can swap hands – but you still know where the money is.

METHOD: "This one deals with physicality, with a real change that you can see," says Salem.

Look away and ask your subject to hold the hand containing the bigger amount of money up to their forehead and really concentrate. Wait 30 seconds. Then look back and tell them to hold their hands out. The blood will have drained from the fist that has been elevated, so the hand will appear lighter.

Charlie Burton

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GET HEADHUNTED

Top jobs are rarely advertised. Instead, the responsibility for finding talent usually resides with an executive-search firm – or headhunters. Moira Benigson and Sally Drexler (*left and right*) of the MBS Group, have worked with clients including Sainsbury's, Apple, BT, Liberty, Nike, Virgin and Jamie Oliver Enterprises. Here's how to get the headhunters to call you.

1 POLISH YOUR CV

No one cares if you were the year-six ping-pong champion – keep things relevant. Make your CV pithy and focus on tangible achievements. "A CV is always a teaser," Benigson says. "Make it as short as possible rather than rambling on."

"Our clients talk in numbers – everything is about the bottom line," Drexler adds. "So your CV should list your achievements and how they have impacted [the business]. Put it very factually: what are your achievements? What are your responsibilities? Where have you been?"

2 GET YOUR TIMING RIGHT

Red flags for headhunters include candidates who have jumped from job to job, have spent too short a time in a position and have obvious gaps on their CV. "The optimum time to move is after a success," Drexler says. "You've gone into a company, you've had a brief and you've made a success of it, then you look at what's next."

3 WATCH YOUR BACK

Trying to leverage an approach from a headhunter with your current boss can turn ugly. "Some people tell their bosses because they think they might get a pay rise," Benigson says. "But the graveyard is full of people who thought they were indispensable."

4 BE VISIBLE

"People who are good and in the online and digital space will talk at conferences," Drexler says. "That is an aspect of your job as well. Meet people, go to [industry] mashups, raise your profile."

"Be visible in the press, write opinion pieces," Benigson adds.

And take care with your online presence. Anything you put on Facebook or LinkedIn is easily sourced by potential employers. Drexler says that she doesn't take the recommendations on LinkedIn seriously as entries are generally posted by friends. "If you're in digital you should have an online presence," she says. "But you've got to be very careful of what you write, how you present it, what you do. It's a very intrusive medium."

5 CLOSE THE DEAL

You got the headhunter to notice you. Now for the job interview. Benigson and Drexler believe that preparation is key. Thoroughly research the company that you're seeing – visit their locations if you're in retail, look at the books if you're in business development, have a clear vision of future development if you're in strategy. "Culture comes before anything technical," Benigson says. "For example, if you're going to a funky young digital company and you're wearing a suit, it's not going to work."

Know what will be required of you in your role and talk about how you'd make a difference.

Greg Williams

PHOTOGRAPHY: MICHAEL PILKINGTON. ILLUSTRATIONS: JEZ BURROWS; JOE SNOW

GET VC FUNDING

Yes, that business idea you jotted on a napkin could be the next big thing. But without finance, it means squat. So how do you secure backing? Julie Meyer, CEO of London-based investment firm Ariadne Capital, which has raised money for the likes of Skype, passes WIRED some tips.

1 **GET THROUGH THE DOOR**
Meyer tends to meet just 30 per cent of new approaches. And don't ask the VC to sign an NDA – it will put them off. So it helps to network: "You're promoting, looking for money, establishing that you are here to stay." If you're successful, you should...

2 **PREPARE THOROUGHLY**
Research who you will meet and practise your presentation. "Get someone to bash around the whole investment strategy – most people forget it's different from the business strategy. Get them to question you." In the meeting, make sure you...

3 **TELL THEM WHO YOU ARE**
Explain where the idea came from in a way that lets you sell your team's abilities. The venture capitalist will look for particular types of people – show that you've got a salesperson and someone who is technical but with good business sense. You also need to...

4 **EXPLAIN THE OPPORTUNITY**
Convince your audience that this is a significant market. "Show there's a big enough problem to solve, and that what you're doing isn't a trivial thing." Suggest how your company would benefit the fund's portfolio. After the meeting...

5 **FOLLOW UP**
The purpose of the first meeting is to get a second meeting – so the best thing you can hear from your target is a request for more information. Send the investor a note to thank them for their time. "If you do that, it really sets you apart," says Meyer.

Charlie Burton

USE CHARM TO GET AHEAD

Charisma isn't hereditary; it's a behavioural skill. Charismatic people don't have magical powers and they aren't necessarily better looking – they just behave in a different way. Tom Salinsky and Deborah Frances-White (*below*) of The Spontaneity Shop – a theatrical company that works with corporate clients to improve employees' interpersonal communication – share their secrets on pumping up your popularity.

1 **BE COMFORTABLE**
Charismatic people are happy to take up space and time. They don't fidget nor do they make unnecessary movements. To feel more powerful, try holding your head still while you speak and deliver your words more slowly. Now try the opposite – try touching your face and speaking faster Notice how diminished you feel?

2 **DON'T COMPROMISE**
Asserting yourself can make you feel more dominant, but this can be at the cost of charm. Yet when we want people to like us, we often become less powerful and assertive. Charismatic people aren't ones to strike a happy medium – they're the ones with lots of power and lots of charm. Be sure to work on both.

3 EMBRACE WEAKNESS

Empower and praise other people – without making them feel patronised. Charismatic people don't feel that it diminishes them to give praise, admit fault or show weakness. Barack Obama, when challenged on his appointment of Tom Daschle (who was caught up in a tax scandal), cheerfully admitted to his cabinet, "I screwed up" – looking no less confident than when giving his victory speech at Grant Park.

4 BE PLAYFUL

Research has shown that conversational playfulness makes people laugh and bond as a group much more than wit or humour. So don't feel pressured to come up with clever one-liners. Being relaxed and cheerful beats trying too hard.

5 KNOW YOURSELF

This framework isn't a one-size-fits-all solution. Your charisma has to reflect your personality, and so everyone's version of these behaviours must be different in order to be authentic. However, the key points of powerful behaviour and empowering others are almost always the same. Helen Mirren, Eddie Izzard, George Clooney, Oprah Winfrey and Bill Clinton are all very different people, but each of them has found ways of being the most relaxed, confident and charming person in any given room.

6 BUILD IT UP

Practice is key. Barack Obama used to have a reputation for being a tedious speaker until he started studying the oratory skills of Baptist preachers. Start small: order your coffee with more authority, but flash a warm smile. Try to make the barista laugh. Feeling bold? Order a round of drinks at a bar, and then tell the person behind the bar you've left your wallet at your seat. If they let you take the drinks, they like and trust you. Remember to go back and pay for them, though.

João Medeiros

PHOTOGRAPHY: MICHAEL PILKINGTON. ILLUSTRATIONS: JEZ BURROWS; JOE SNOW

JOIN THE SINGULARITY

The singularity – that moment when we'll upload our minds on to computers – is coming. Keith Kleiner, associate founder of the Singularity University, and Terry Grossman, co-author with Ray Kurzweil of *Transcend: Nine Steps To Living Well Forever*, prepare you.

READ RAY KURZWEIL

The inventor thinks that AI will surpass humans by 2045, so get on board now.

LIVE HEALTHILY

Keep your brain and body in top condition. Kurzweil takes 250 supplements and drinks ten glasses of water and ten cups of green tea *each day*.

START ARCHIVING

And not just your data: "I take samples of abdominal fat from my patients," says Grossman. "Then I isolate the stem cells and cryonically store them, just in case."

Tom Cheshire

MANIPULATE THE UK

Let's say you're David Cameron, out to save the economy while enhancing the nation's eco credentials. You could use tax penalties and incentives to cut spending and make us recycle more. But why not wield powerful tools of social persuasion whose effectiveness is well documented? Robert Cialdini and Steve Martin of scienceofyes.com show how social psychology and behavioural economics can create better-behaved citizens.

1/ Use social proof: In a pilot study last year, Her Majesty's Revenue & Customs sent out experimental tax demands to a small sample of UK residents. Rather than threatening penalties if they failed to pay on time, the letters reported that the vast majority of UK taxpayers meet their deadline. Early results deemed the pilot to be a success, with an increase in more timely tax returns.

The strategy also works for cutting citizens' carbon footprints. For the last 18 months, tens of thousands of Californians have received a special utility bill. It contains data about their energy consumption – and their neighbours. Households deemed the most efficient are rewarded with a smiley face on their bill. Energy cuts of almost three per cent have been recorded since the smileys were added, regardless of the size of the property, residents' income or average age.

2/ Manipulate social norms: **Social psychologists have noted an odd quirk of human behaviour. By pointing out what others are doing, they can often influence more people to do the same – even if the behaviour is socially undesirable.**

Last year, people failing to attend GP and hospital appointments cost the NHS over £600 million. Perhaps one reason is a common sign found on waiting-room walls pointing out the large number of people who don't turn up. These signs normalise non-attendance, so why not promote more positive behaviour? If it cuts non-attendance by just ten per cent, that's a £60 million saving for a simple change of words.

3/ Publicise desirable change: It makes sense to persuade people to be more energy efficient and embrace recycling. But what's the best incentive? When the Toyota Prius was launched in the US, large tax breaks were offered as an incentive for drivers to "go green". But when the incentives were withdrawn after a couple of years, Prius sales rose by another 70 per cent. Although the tax incentive had been effective, something even more powerful was now influencing people's decisions: Prius drivers were publicly declaring their green credentials.

Earlier this year the *Journal Of Personality And Social Psychology* published a series of new studies showing that people are most likely to choose energy-efficient green products when other people around them can see that they had done so. Surprisingly, the green products also had to be at least as expensive as the non-green ones.

Over to you, Prime Minister...

Robert Cialdini is Regents' Professor Emeritus of Psychology & Marketing at Arizona State University. Steve Martin is director of Influence At Work (UK). Along with Noah Goldstein they are authors of Yes! 50 Secrets From The Science Of Persuasion *(Profile Books).* scienceofyes.com

WARNING! TUCKER FILTH AHEAD

INSULT WITH STYLE

Malcolm Tucker's colourful linguistic creations have spread faster than a rent-boy's cheeks. Here's Tucker's X-rated guide to delivering the perfectly withering put-down – so read the $%&# on, or $%&# the $%&# off.

1 **STRETCH THE METAPHOR**
Tell your target they're "as useless as a marzipan dildo", or "about as secure as a hymen in a south London comprehensive". Above all, use your (fetid) imagination.

2 **MILK POP-CULTURE**
This one always works: "You know what you are? You're a fucking human dartboard. And Eric fucking Bristow's on the oche throwing a million darts made of human shit right at you."

3 **THINK BODILY FUNCTIONS**
Be bold: "Allow me to pop a jaunty little bonnet on your purview and ram it up your shitter with a lubricated horse cock." Or: "I'll fuck you harder than Ron Jeremy and with less warmth."

4 **SHOW YOUR REVULSION**
Say: "I'd stop and chat, but I'd rather have Type 2 diabetes." Or: "I'll stuff so much cotton wool down your fucking throat it'll come out your arse like the wee tail on a *Playboy* bunny."

5 **AVOID SUBTLETY**
Tell them they've "laid a big fat egg of solid fuck", but before berating them, warn them that it "might be advisable to wear brown trousers and a shirt the colour of blood".

Fuckity bye, then.

The Thick of It: The Missing DoSAC Files is published on November 4 (Faber & Faber, £12.99). *The Thick of It: The Complete Boxed Set* is out now (BBC DVD, £34.99). *The Thick of It* is written by Armando Iannucci, Jesse Armstrong, Tony Roche, Simon Blackwell and Ian Martin. Chris Addison will be performing his new stand-up show at the Edinburgh Festival Fringe in August. He tours the UK this autumn – for information, see *chrisaddison.com*

PHOTOGRAPHY: JAMES DAY

TRACK YOUR ENTIRE LIFE

Everything counts, so why not tot it all up? That's the basic premise behind life-tracking, a system of using modern data-analysis tools to measure every aspect of life: from heart rate, to sleep, to personal productivity. Here's how to start logging your own life.

1 **START WITH INPUTS**

If you have an iPhone, Lance Armstrong's *Livestrong* app will help you slice and dice all the food you devour each day. Enter everything you gobble your way through, and it automatically calculates the calories, cholesterol, sodium, fat and other nutritional data.

2 **MOVE TO OUTPUTS**

There's no better tool for measuring physiological data than the Garmin Forerunner 310XT. Thanks to the combination of heart-rate monitoring and GPS, it tracks your ticker, distance travelled and movements. Used with a foot-pod, it can also count your steps.

3 **SUM THE TOTAL**

Once you know your bodily inputs and outputs, it's helpful to see what the net-effect is by tracking with a smart scale. The Withings Wi-Fi-connected body-scale will measure your weight, body-mass index and lean and fat mass, and transfer that data to an online dashboard.

4 **MAP YOUR MIND**

While the body is measurable in raw numbers, the mind is more subjective. But it too can be turned into data. *Mood Tracker* enables iPhone users to track their feelings and state of mind with smileys and will graph your mood over time.

5 **PERFECT PRODUCTIVITY**

You might sit at your computer all day, but what are you actually doing? A new generation of desktop apps, such as *RescueTime*, help you log the online distractions that dominate your day. Productivity-eating websites can be identified, blacklisted and blocked.

Mathew Honan

The most **DEADLY WEAPONS** in Iraq and Afghanistan aren't AK-47s or grenades – they're **ROADSIDE BOMBS** made from petrol cans, garage-door openers and fertiliser. This is how the US military is learning to **FIGHT** back

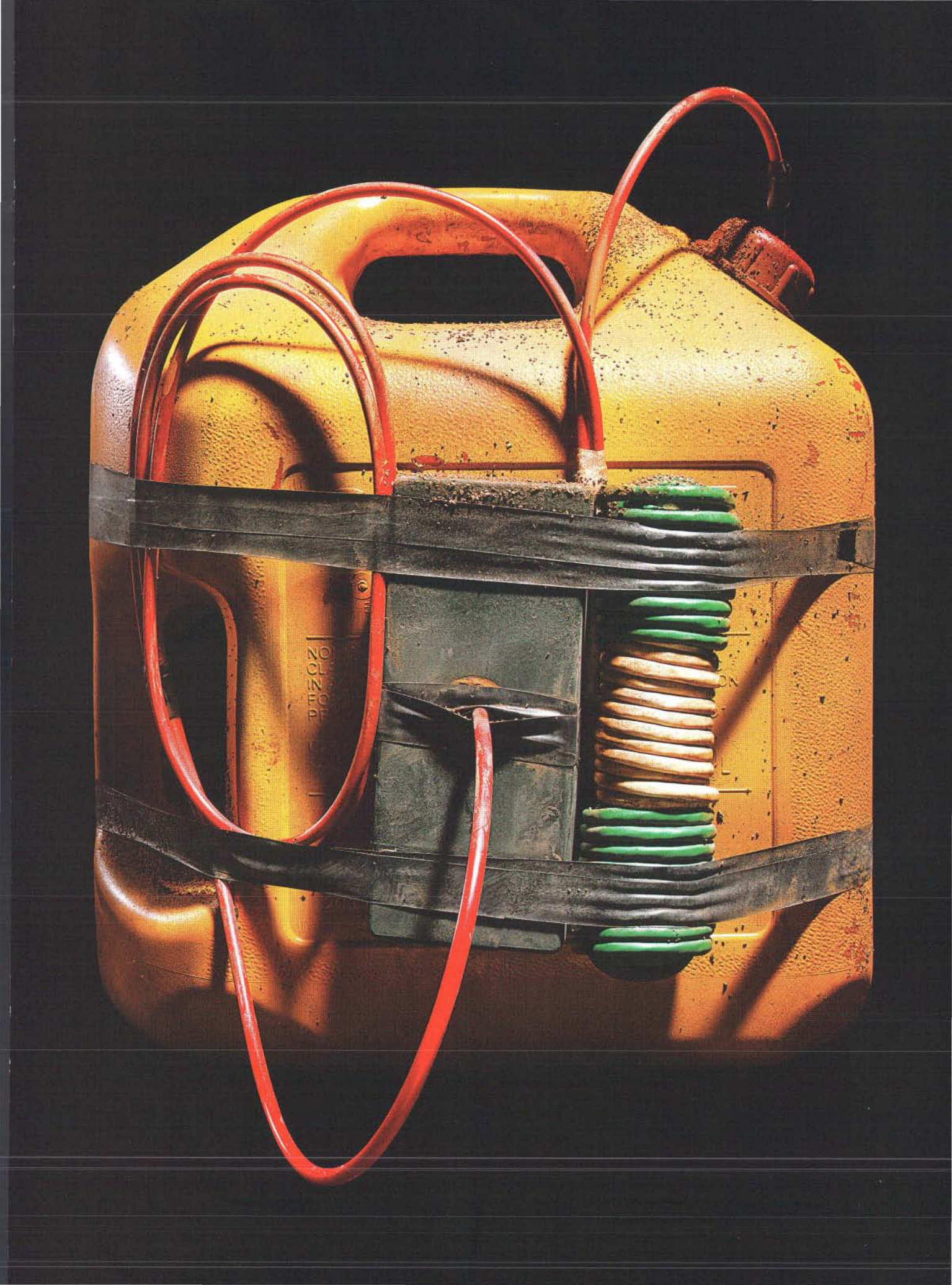
State of the art

by ADAM HIGGINBOTHAM

One afternoon at the tail end of March, inside a cinder-block bunker on a small island in Chesapeake Bay, Scott Schoenfeld is waiting to blow something up. On a monitor in front of him is a grainy image of a rusty steel box about 20 metres away. Inside is an explosive charge and an experimental target. A big, softly spoken computational scientist wearing a black polo shirt, jeans and wraparound sunglasses, Schoenfeld is one of the chief armour researchers for the Joint Improvised Explosive Device Defeat Organisation, or Jieddo, the Pentagon agency dedicated to combating IEDs. He won't say how much explosive he's using today, or what, exactly, the target is. The charge is modelled on an IED discovered abroad, and the details remain sensitive, if not classified.

"We're trying not to give anyone ideas they don't already have," he says. But he will acknowledge that the charge is lethal. "Unprotected, it would kill many people. Pounds of high explosive are involved." He hands me a pair of ear defenders. "The boom," he says, "will be rather large." Outside, a siren blows three times. Standing at a rack of instruments in the corner of the bunker, the range operator announces, "Reset. Arm. Three. Two. One. Fi-"

Photography: TOM SCHIERLITZ



On the monitor, a cloud of grey smoke puffs from the box, which is open at one end, and then a fraction of a second later comes the boom – a sharp crack loud enough to be heard through cinder block and ear defenders, drowning out the conclusion of the countdown. A shock wave shakes the walls of the bunker. After the all-clear, Schoenfeld leads the way outside. Nothing remains inside the testing chamber but a burnt smell and the charred wooden fragments of the framework that held the charge and its target. The 15cm-thick, steel-plate walls of the chamber are as ragged as wet cardboard, buckled and pockmarked by the blasts and shrapnel from hundreds of tests.

Schoenfeld and his team have conducted experiments here at the US Army's Aberdeen Proving Ground for six years, and their research – which has contributed to the creation of everything from the first emergency armour kits for Humvees to the mine-resistant ambush-protected vehicle – is among the most successful sponsored by Jieddo. Schoenfeld has held weekly video conferences with troops in the field for several years. There was a time he'd get to know soldiers only to have them sign off from a video chat and never return. "It was very sad," he says. "The output of these devices was devastating." These days, things are different. He shows me a 20cm-thick block of military-grade steel with a 5cm-wide hole blasted all the way through by shrapnel from a test IED charge. New armoured vehicles can take damage like this, Schoenfeld says, and the occupants can tell him about it on video afterwards. "I get people standing in front of holes like these, smiling," he says. "They say, 'Yeah I got back out and shot the guy that did this.' "

Jieddo was formally signed into existence by the US Department of Defense just four years ago. But it has its origins in a request written by the chief of US Central Command, John Abizaid, to his superiors at the Pentagon in mid-2004. As the number of casualties caused by IEDs in Iraq mushroomed, he insisted that the only solution was a "Manhattan Project-like" marshalling of scientific and military resources. Since then, Jieddo has gathered a staff of more than 3,600 government employees and contractors, established projects with all four military services and every intelligence agency, and spent more than $17 billion. In Iraq, Jieddo has succeeded in drastically reducing the carnage caused by IEDs. At the start of the war in 2003, every device that troops encountered resulted in, on average, the injury or death of at least one member of the coalition forces; by 2009, insurgents had to put down nine IEDs to cause a single casualty. But IEDs remain the principal killer of US troops in combat. In Afghanistan – where the number of IED incidents doubled in 2009 and caused 75 per cent of casualties in some areas – Jieddo faces a new generation of more ingenious, and bigger, bombs.

At the northern Virginia headquarters of Hazard Management Solutions, a private contractor that provides intelligence and training to Jieddo, Mark Maginess draws a diagram to illustrate the central problem of the counter-IED struggle. Maginess, a veteran bomb-disposal technician who learned his trade with the British Army in Northern Ireland, is director of training at HMS and runs a "know the bombmaker" course for a US military agency – he won't say which. He sketches a simple graph plotting the sophistication of IEDs against time. He adds a diagonal line moving steeply upwards: as time goes on and insurgents learn more about bombmaking, he explains, their devices become more complicated. Jieddo must address each new device.

But not only will the insurgents keep inventing new bombs and techniques, they're also free to fall back on ones they've already used: "They can move up and down this spectrum, from complex to easy," Maginess says. Jieddo, on the other hand, must always deploy every countermeasure in its arsenal, adding more as each new device appears. "It's only ever going to get worse for us." And the way the Department of Defense works, a new IED need appear only once to require a corresponding, costly antidote. "I can take $600, go into a bazaar, and make a device," says one senior Jieddo officer. "And I can tie up $1.2bn to $2bn of US money by doing it."

This escalating arms race, pitting kitchen-table bombsmiths against US-government technologists, began in the early months of the Iraqi insurgency. The first IEDs were often simple radio-controlled bombs, made from two or three 155-millimetre artillery shells set off by a signal from a cheap household gadget, like a key-fob car-alarm switch or a wireless doorbell buzzer. US troops, travelling in unarmoured Humvees, were defenceless against them until each of the services hastily bought hundreds of radio-frequency jammers – with codenames such as Cottonwood, Ironwood, MICE, ICE, Warlock Red, Warlock Green, Jukebox and Symphony – capable of generating an invisible hemisphere of electromagnetic energy that could drown out those trigger signals. Jieddo would oversee the deployment of more than 40,000 jammers in Iraq.

The bombers quickly learned how to circumvent the electronic countermeasures. They used handheld radio-frequency meters and bombs with dummy trial-and-error firing circuits to figure out which part of the spectrum the jammers blotted out and how big

A RAGGED SLUG FROM ONE OF … CAN PENETRATE A TANK 100

the jamming field was. Then they simply switched to new remote controls that used bandwidths beyond the jammers' range. When US technicians introduced electronic countermeasures to jam low-power radio-control devices such as garage-door openers and car alarms, insurgents moved to high-power devices, including two-way radios and extended-range cordless phones. Then they moved on to mobile phones in every local network, from 1G to 3G.

Although this race had been run before, it had never taken place at such speed. With one of the most intensive and ingenious programmes of homegrown bombmaking R&D in history, Northern Ireland's Provisional IRA worked its way through every available bandwidth from model-airplane controllers to mobile phones. It took them 30 years. But Iraqi insurgents innovated on internet time. By February 2005, they'd managed the same evolution in just 18 months. Yet radio-control devices, however sophisticated, represented only the middle of the IED technical spectrum. It wasn't until the summer of 2004 that Iraqi bombsmiths reached into the high end with the explosively formed penetrator, or EFP. Using technology developed during World War II, today's EFPs are made from a short length of steel or PVC pipe packed with explosives, sealed and capped with a concave copper disk. When the explosives detonate, the blast energy inverts the copper plate into a ragged slug travelling more than 1.5km per second and capable of punching through tank armour 100 metres away. Iranians used

IED MODELS BASED ON ACTUAL BOMBS, CONSTRUCTED BY PROP HOUSE WEAPONS SPECIALISTS LTD

THESE BOMBS
METRES AWAY

EFPs during their eight-year war with Iraq and later supplied the technology to Hezbollah guerrillas in Lebanon. Bomb-builders there added passive infrared triggers, sensors that detect motion by responding to changes in temperature – such as that created by the engine of a passing truck. Because they don't use radio frequencies as triggers, they're invulnerable to electronic jamming.

In Iraq, the effectiveness and frequency of EFP attacks proved so devastating that soldiers improvised their own countermeasures. One bought a toaster in a bazaar and hung it from a pole welded to the front of his Humvee – a heat decoy. This and similar ideas led, in May 2006, to one of Jieddo's first innovations: the Rhino. The Rhino used a glow plug – an electric heating element for warming diesel engines before ignition – housed in a steel box on the end of a three-metre boom. It worked so well that it could not only trigger an EFP and take the impact of the high-velocity metal slug but, on at least one occasion, continue working afterwards. It took six weeks for the insurgents to respond. They adjusted the firing angle of their EFPs so the slug struck three metres behind the decoy. Jieddo countered with the Rhino II, fitted on an adjustable-length boom. Along with electronic jammers, the Rhino II became standard on US vehicles in Iraq. But at the beginning of this year, US forces in Iraq reported a new version of the passive infrared trigger, nicknamed the Black Cat. It looked exactly like a regular passive infrared sensor, but the motion detector was altered to be triggered by radio frequencies. Shielded to prevent it from being set by household radios and with reduced reception range, the new device is one of the most devious yet. Designed to detect the passing bubble of a coalition jamming system's powerful radio field, it has brought Jieddo full circle: it's an IED that will detonate only when it detects an IED countermeasure.

Sitting in his kitchen in northern Virginia, Mark Wickham shows me a thin paperback book with a skate-punk cartoon cover depicting a slavering ghoul brandishing a bubbling coffee can. It's a bombmaking manual called *Home Workshop Explosives*, credited to "Uncle Fester". "I bought this at Borders," Wickham says, shaking his head in disbelief. "Twenty dollars." At 55, short and bespectacled with stiffly parted salt-and-pepper hair, Wickham has spent his entire career studying the methods and networks of improvised-bomb makers. It's a subject he addresses with an intensity born of personal experience. "He was blown up," his wife explains. "That's why he's so passionate about getting IEDs right: he got it wrong." While a captain with the 321 Explosive Ordnance Disposal Squadron of the British Army in Northern Ireland, Wickham was working to defuse a blast incendiary device one night in 1980 when it exploded, engulfing him in a ball of flame. He was on life support, underwent extensive reconstructive surgery and never regained the hearing in his left ear. Later, he became one of the UK's most senior IED specialists; five years ago he became Jieddo's expert in weapons technical intelligence.

The process begins on the battlefield. Military bomb squads collect and bag material from the scenes of IED incidents and send it to labs nearby, where DNA and latent fingerprints are collected and checked against databases. Bombs recovered intact are dismantled and flown out for analysis at facilities around the world, including an FBI lab in Quantico. From there, the components are distributed: at Aberdeen, Scott Schoenfeld's team builds surrogate charges to test against different armours. In Virginia, members of Jieddo's Technical Gaming Team replicate the triggers for trials of experimental countermeasures to be carried out in Arizona. At the Army's National Training Center at Fort Irwin, California, analysts build their own versions of the weapons and conceal them in the combat-simulation zone known as the Box, to test troops in their final weeks of training.

All bombmakers leave a signature in their devices – whether it's a pattern of hot-gluing wires to a circuit board or the repeated use of a favourite component. One Afghan IED builder has been linked to at least 90 separate pressure-plate triggers made from plywood and the four heavy springs from old-fashioned bicycle seats. Every one of his triggers has five separate mechanical characteristics in common. And there is biometric evidence, too: "When he wound the wires together to attach them to the springs for the contact, he left his DNA behind," Wickham says. The weapons technical intelligence process has also revealed a broader scheme at work. The tactics of today's insurgent bombmakers are the product of a long-simmering melting pot of global terrorism: expertise developed by the IRA and disseminated in a clandestine exchange of bombmaking wisdom that included members of the Spanish separatist group Eta and the Farc guerrillas in Colombia. In Iraq, Wickham recognised techniques he'd seen in Northern Ireland 30 years ago. "I can take you to Baghdad and show you a command wire set up in October '07," he says. "I can take you to South Armagh and show you exactly the same tactical design from 1980." US military-intelligence analysts already suspect that the lessons learned by IED cells in Baghdad are being put into practice by the Taliban. "If it works in Iraq long enough," one analyst says, "they'll start moving it into Afghanistan."

In the past two years the narrow mountain passes of the Hindu Kush and the sparsely populated desert flatlands of Helmand have become the new front line in the battle between bombmakers and

CAT AND MOUSE: A CASE STUDY

When insurgent bombmakers come up with a new way to trigger a weapon, the US military devises a countermeasure. Insurgents figure out how to get around it, and the cycle continues. Here's how that played out with a device called an explosively formed penetrator (EFP).

1 / JAMMER-PROOF BOMBS (SUMMER 2004)
Insurgents start using EFPs – lengths of pipe packed with explosives that launch a molten slug of copper. Because they're tripped by the engine heat of passing vehicles, coalition electronic jammers prove useless.

2 / BOMBPROOF DECOYS (MAY 2006)
Individual soldiers improvise heat decoys, like a toaster hung on a pole in front of a truck, which inspires a countermeasure: the Rhino. It consists of a heating element housed in a steel box and extended on a 3m boom.

ILLUSTRATIONS: NOOK

Jieddo's counter-IED technicians. Afghan bombmakers, faced with the sophistication of US countermeasures developed in Iraq, have begun moving backwards down the continuum represented by Mark Maginess's graph. After their radio-control bombs were smothered by jammers, the Taliban turned not only to "command wire" – physical connections between trigger and bomb – but also to the even more reliable "command pull", a simple switch attached to monofilament fishing line or even a piece of string. With these, at least, the triggerman must remain nearby for the attack and is therefore relatively easy to catch or kill. But almost all of the devices encountered during 2009 by Jieddo's Afghan operation, Task Force Paladin, were simpler still and harder to locate: large bombs triggered by pressure plates buried in the middle of dirt roads. "You drive over it, your weight initiates the pressure plate – blows up under your belly where it's most effective," says Jeffrey Jarkowsky, Paladin commander until late last year.

These rudimentary mines can sit for days or even months waiting for a victim. They're often made from whatever is at hand in a rural environment, like the bicycle-seat springs or two carpentry saw blades tensioned into a bow – anything that lets two contact surfaces meet to complete a circuit. More recently, the pressure plates have been built with less and less metal. One type of device uses only two strips of aluminium tape; another, single strands of wire and contacts made from fragments of the graphite core from a C-cell battery. As a result, the metal detectors used by US route-clearance teams are becoming ineffective.

And since the stocks of military ordnance left over from the Soviet war have been depleted, three quarters of Afghan IEDs have been made not with pilfered artillery rounds but with more common agricultural ingredients such as ammonium nitrate fertiliser. Packed into 20-litre plastic containers and buried in a dirt road, these charges are utterly invisible to metal detectors. Task Force Paladin is using ground-penetrating radar to find them, but that works only from right on top of a bomb, increasing the risk of setting it off. And many chemical sniffers deployed in Iraq detect only the molecules produced by decaying TNT – not ammonium nitrate.

Jieddo scientists have been working for four years on a means of detecting homemade explosives at a distance; a solution has so far eluded them. They have also been trying to figure out how to detect the electrical blasting caps used to detonate many types of IEDs, so they can be set off from a safe distance. Perhaps inevitably, some of the best means of beating the Afghan bombers have proved to be the simplest: many vehicles are now protected by front-mounted rollers that trigger mines ahead of a convoy. If in doubt, troops are trained simply to get out and look for clues like disturbed ground or a pile of rubbish that wasn't there before. "Even today, with all the technology," says Jarkowsky, "the best detector of an IED is the human eye."

In the meantime, the kitchen-table arms race continues. At the National Training Center at Fort Irwin, Jieddo hosts ten one-month rotations of troops a year, hoping to make them familiar with IED innovations just as insurgents start using them. "As soon as we stop training in one type of device, that's the one they start using, because that's the device that becomes effective," says Jeffrey Gagnon, who oversees Fort Irwin's Jieddo unit. "So we have to keep the training up across the whole spectrum." The task of trying to keep up with the Afghan bombsmiths falls to the men of the Terrorist Exploitation Network workshop, housed in a dun-coloured metal shed on the outskirts of the Fort Irwin complex. From here, Rodolfo Llamas and his men – with the help of two contractors who do nothing but make IEDs five days a week – distribute 300 to 500 replica bombs a month into the replica Afghan and Iraqi towns that make up the Box. Each device is handmade and works exactly like the original, but detonates a pair of non-lethal M-80 simulated charges.

Late one afternoon in April, Llamas shows me the latest device they've been working on, just in from Afghanistan. A neatly made plywood box about 20cm high and 12cm square, it has a length of replica detonation cord emerging from the base. Llamas pulls open the box, revealing a layer of soft foam and a wooden plunger attached to the lid. When stepped on or driven over, he says, the foam is compressed and the tip of the plunger, which is saturated with a chemical, descends into a chamber at the bottom of the box. That chamber contains a second substance, and when the two chemicals mix, a reaction ignites the end of the detonation cord, which leads to an explosive charge. The box is the conclusion of years of reverse evolution in insurgent-weapons technology. Without a power source, a blasting cap, or a single piece of wire or metal contact, it has no electromagnetic or metallic signal. Linked to a charge mixed up from odourless homemade explosives, packed beneath a road, it's all but impossible to detect.

Although the wooden IED was found and photographed in Afghanistan and then reconstructed here in the Mojave Desert, the insurgents apparently remain one step ahead of technicians here. The pyrotechnic chemical mix remains a mystery. "We don't know what it is yet," Llamas says. "We're still trying to figure that out." W

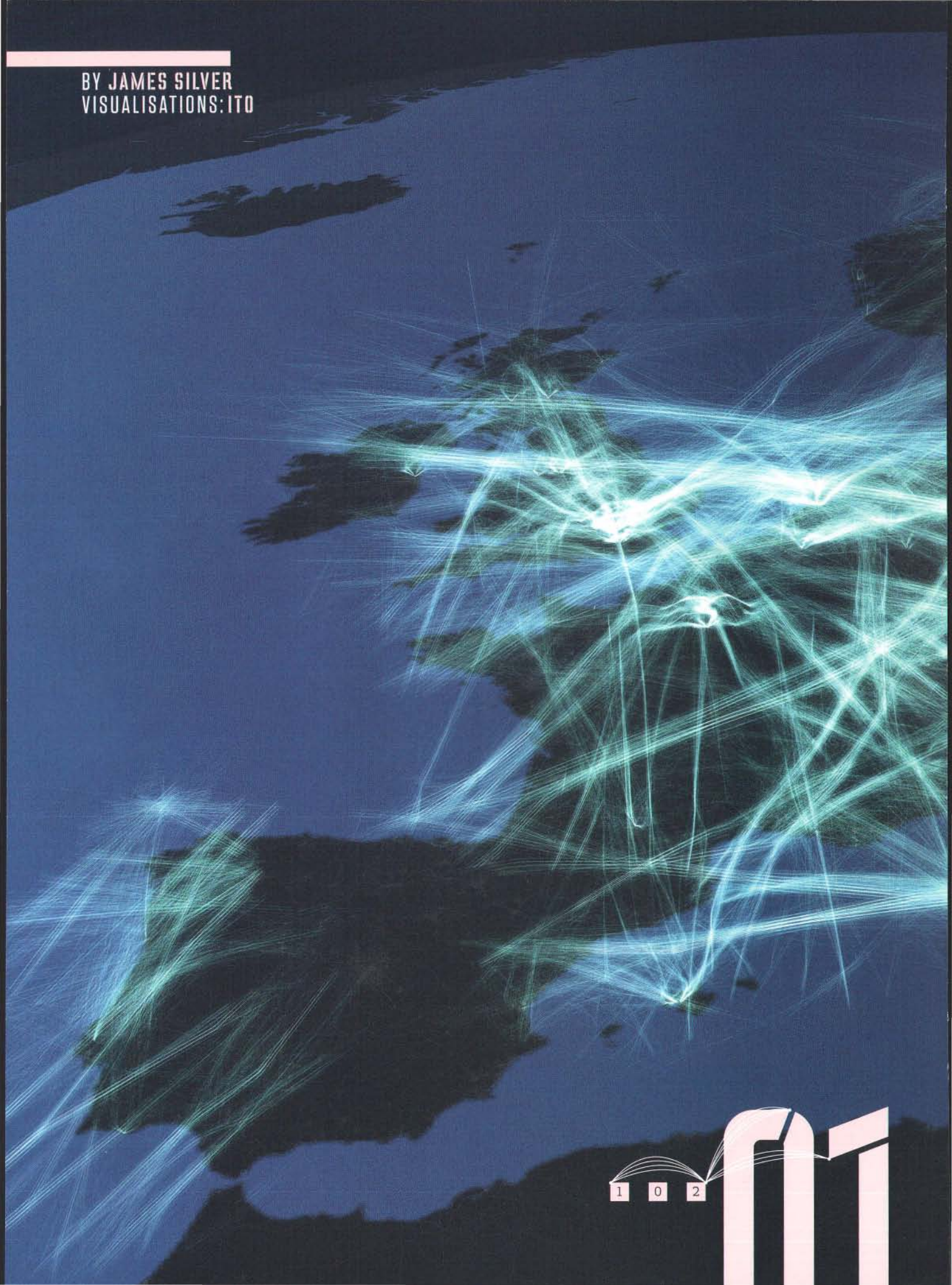
Adam Higginbotham is a writer based in New York City (adam@adamhigginbotham.com). He wrote about the inkjet counterfeiter in our 11.09 issue

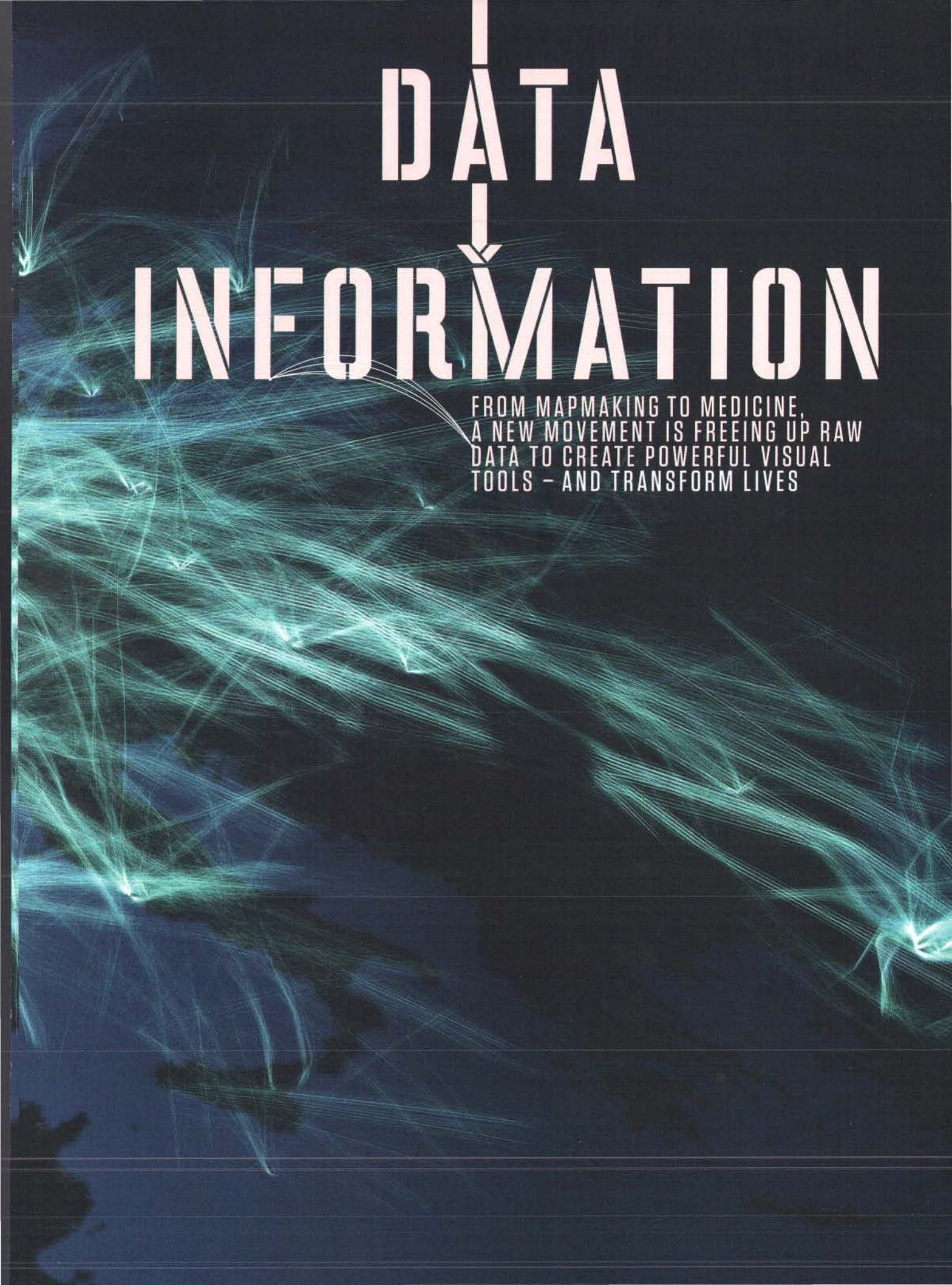
3 / DECOY-PROOF TARGETING (SUMMER 2006)
Insurgents recalibrate the aim of the EFPs, angling them backwards to account for the decoy. EFPs comprise just a small percentage of roadside bombs, but they soon account for hundreds of fatalities.

4 / BOMBPROOF ADJUSTMENTS (LATE 2006)
The Rhino II, which costs less than $2,000 and has an adjustable-length boom, continually changes the position of the decoy. More than 16,000 Rhino IIs are deployed in theatres in just 30 months.

5 / JAMMER-TRIGGERED BOMBS (EARLY 2010)
New EFPs ignore heat signatures and are triggered by the high-power radio waves emitted by jammers. In other words, the latest bomb is set off by the countermeasure that defeated its predecessors.

BY JAMES SILVER
VISUALISATIONS: ITO





DATA ↓ INFORMATION

FROM MAPMAKING TO MEDICINE, A NEW MOVEMENT IS FREEING UP RAW DATA TO CREATE POWERFUL VISUAL TOOLS – AND TRANSFORM LIVES

hours into his deployment in Haiti, as part of the Red Cross's first rotation after January's 7.0-magnitude earthquake flattened much of Port-au-Prince, Kjeld Jensen was busy making maps.

His unit had arrived by bus from the Dominican Republic the day before and the driver had promptly lost his way. "We lost at least three-quarters of an hour, I'd say," says Jensen, who was heading the joint Danish-American IT & Telecom Emergency Response Unit. "And with eight to ten people on the bus, that adds up to quite a few lost [person] hours."

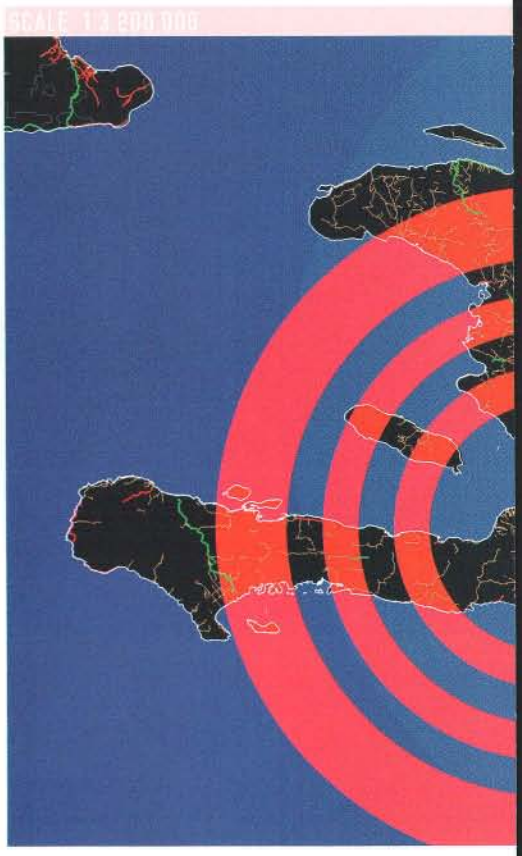
Of the logistical headaches of disaster-relief work, mapping is the most urgent. If they're lucky, Red Cross responders are handed basic maps printed out from the internet before they go, says Jensen, who is now back in Norway. But on the ground, they have to work closely with local teams, MapAction, which specialises in drawing up maps for disaster areas, and the UN. They use Google Earth to plot the locations of camps for internally displaced persons [IDPs], logistics warehouses and radio repeaters. "You can hack a KML file [which allows users to customise Google maps] in minutes and share it with others," he says.

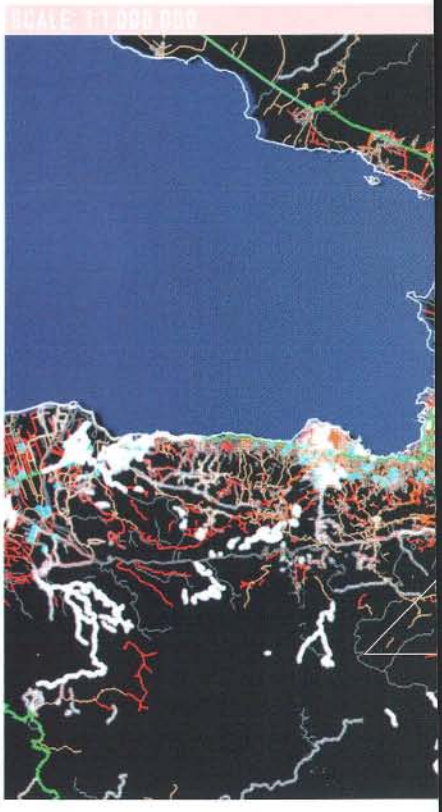
As unit leader, Jensen quickly built up his own database of GPS waypoints for camps, water pumps, logistics hubs and the airport. But shortly after his arrival, word reached him about OpenStreetMap (OSM), an open-source, worldwide editable mapping project, and this was to transform his mapmaking efforts. In the immediate aftermath of the earthquake, a small army of OSM volunteer mappers across the world had set to work using high-res satellite imagery to map Port-au-Prince and the devastated city of Carrefour. Within 48 hours both cities had been comprehensively mapped.

News of OSM's feat spread quickly among crisis responders. "The link to the maps was circulating just a few days after we arrived," says Jensen. "It was new to us, but I installed their maps on the Garmin [GPS] units, which supported it." When the Red Cross switched the location of its main base, Jensen and his driver got lost trying to find the new HQ. "I had OSM on my Garmin Oregon. I radioed to a colleague who knew the location and we easily found it on the map." He adds: "[OSM] was a big time-saver for me several times. It made a difference in this operation."

Many of OSM's volunteer mappers see themselves as part of a worldwide "open geo-data" movement. Maps have traditionally been restricted by copyright and are often expensive to acquire. OSM, however, was conceived as "Wikipedia meets maps", aiming "to map the world and give the data away for free". The "Wikification" of mapping appeals to 30-year-old, London-based web developer Harry Wood, who's been mapping for OSM since 2006. "To me, it's about releasing the data, making sure the underlying data is free," he says. "So many exciting technological things can happen when geo-data is released." He was one of "about 300" volunteer OSM "armchair-mappers" who mobilised in the hours after the earthquake and set about mapping the disaster zone, street by street.

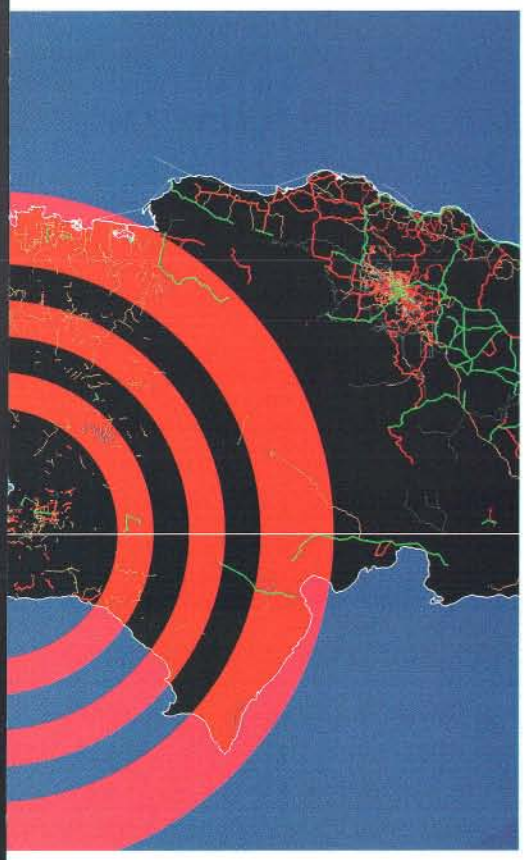
When news first broke, Wood had yet to grasp the scale of the catastrophe. He began by "doodling in" streets visible in Yahoo imagery, which was made available to OSM in December 2006. When the true picture began to emerge, work by OSM mappers began in earnest. Geo-data was taken from a variety of sources ranging from Yahoo to old CIA maps – the access to much of it arranged through the CrisisMappers network of open-data mappers. The response was co-ordinated through online

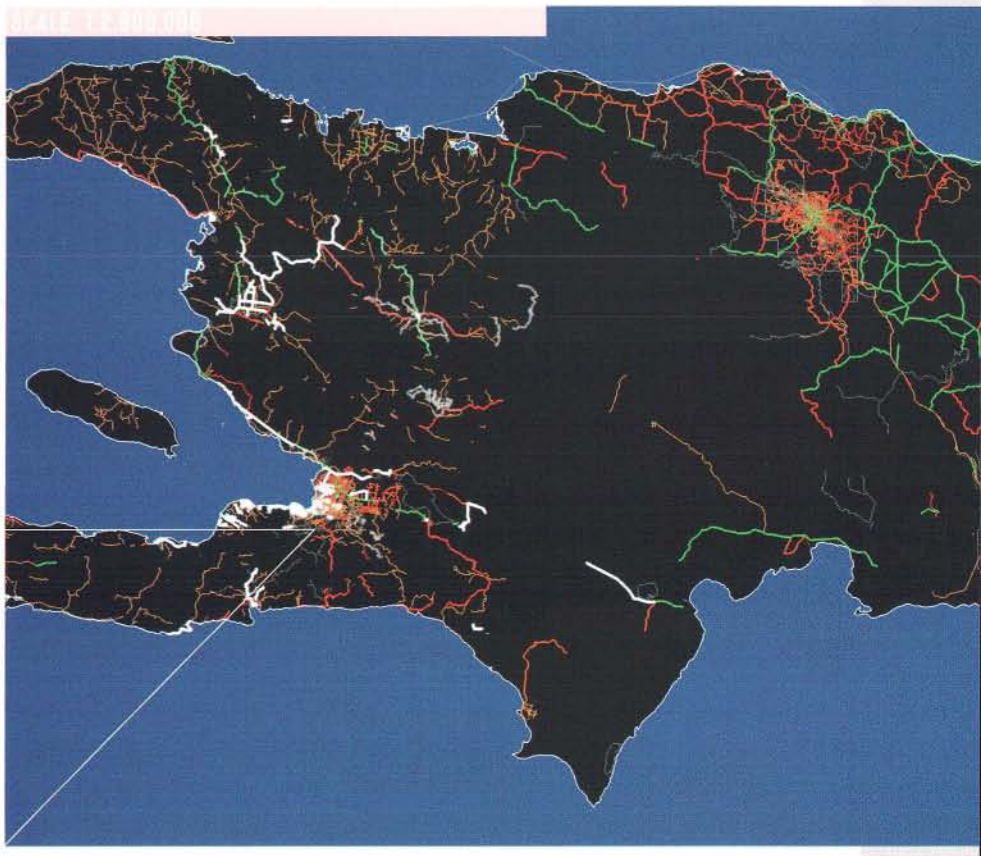


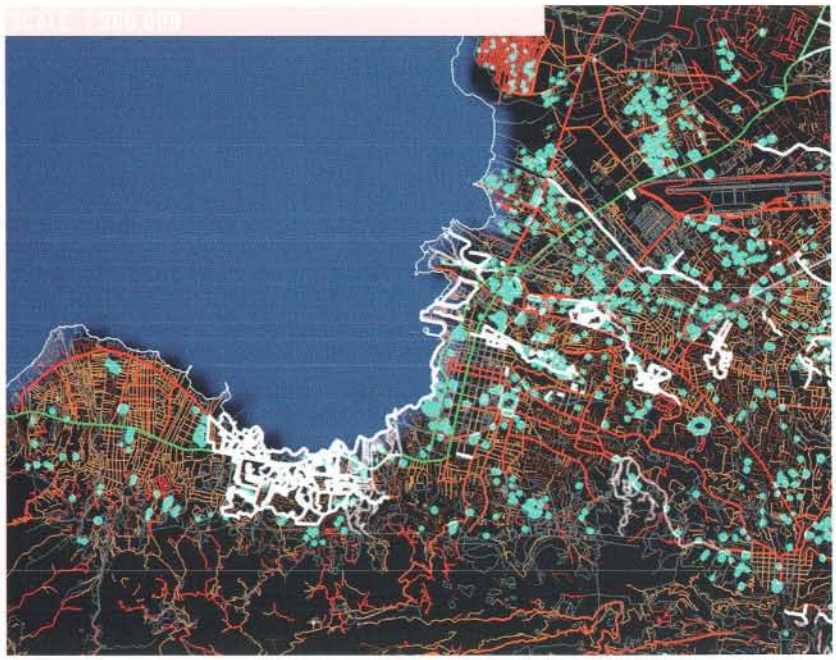


PREVIOUS SPREAD

When air-travel restrictions caused by volcanic ash over Europe were lifted on April 21, traffic began to return to normal. In this snapshot of that day, based on data from Flightradar24.com and RadarVirtuel.com, white lines show individual flight paths. Converging lines are traffic hotspots.





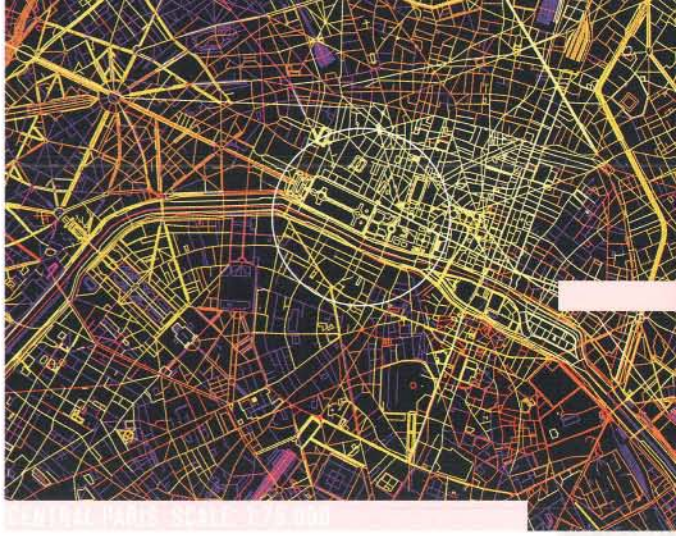


When an earthquake hit Port-au-Prince on January 12, OpenStreetMap volunteers traced road networks on to satellite photos (green for primary routes, red for secondary). The blue areas represent internally displaced persons' camps and are detailed enough to show individual tents.

03

EUROPE / 2009

This render of Europe shows data uploaded by some of OSM's 260,000 registered users. Brighter areas indicate more recent uploads. The map offers great detail: Paris and, magnified further, the Louvre (*circled*) are discernible in zoom views from the same image.



CENTRAL PARIS SCALE 1:75,000

channels, including an OSM Haiti WikiProject page.

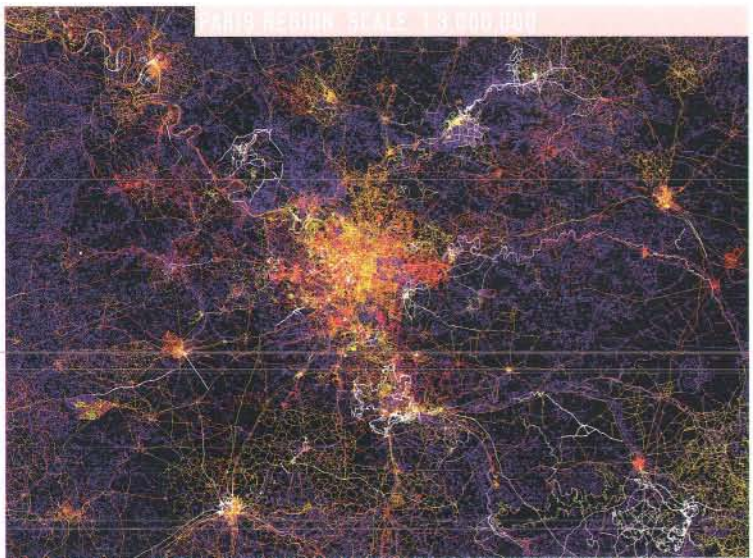
"Quite a few people in the community, me among them, had a feeling that OSM had a lot of potential in a disaster-recovery situation," Wood explains. "When the earthquake struck we looked at what could be traced in Haiti from Yahoo. Yahoo had reasonably good coverage and no one had used it much. But 24 hours after the earthquake, DigitalGlobe and GeoEye [satellite-imaging services] also released aerial imagery at a much higher resolution than Yahoo's. That made a huge difference to us."

OSM's efforts in Haiti, and beyond, continue. Mikel Maron, instigator of OSM's response to the earthquake and chairman of its data working group, drew up the Humanitarian OSM Team's strategy for Haiti. Since the initial flurry of post-quake mapping activity, the organisation has three times sent teams to the country to increase the project's visibility among NGOs, run training workshops and improve the quality of the data being gathered.

OSM mappers were called into action again when an 8.8-magnitude earthquake off the coast of Chile took place just weeks after the Haiti disaster. This time, however, access to high-quality satellite imagery was heavily restricted, hampering their effort. "OSM already has an awesome global network, that's key," says Maron. "But satellite imagery is so important. In Chile, the channels to receive imagery free of licensing restrictions were not as open, so we're looking for partners in that, especially at the UN. We want to be ready for the next crisis."

OpenStreetMap was launched on August 9, 2004, by University College London "dropout" Steve Coast, who began what he calls his "bedroom project" after growing frustrated at the lack of royalty-free maps in the UK. "I had a GPS unit and a laptop with Linux, and there were various bits of open software to talk to the GPS, to plot your position, but there was no data," says the 29-year-old, who is now working on various Linux and open-data projects from Denver, Colorado. "So what I ended up doing was downloading copyrighted map pictures from sources like Microsoft MapPoint. They were pretty useless, because they were images not data, so I figured it would be easy to make my own map of central London. And if I could make the software that could do that for me, then I could just open it up for everyone else and we could make a map of the world, jigsaw-puzzle like."

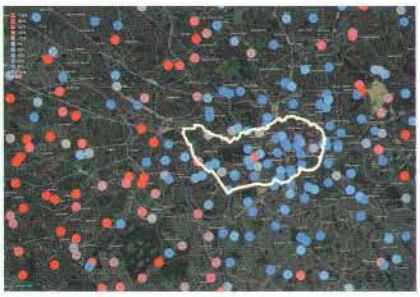
Today, the non-profit OpenStreetMap Foundation claims over 260,000 members in 30 countries. It has also spawned a commercial sibling, CloudMade, which was launched in 2007 by Coast and business partner Nick Black "to provide services on top of OSM". Expanding the open-map project remains at the heart of the foundation's purpose, but the community has also launched projects such as OpenCycleMap.org, which lists national and regional cycle routes across the world, and is producing iPhone apps such as *Atm@UK*, which locates your nearest cashpoint.



PARIS REGION SCALE 1:1,000,000

Less than three weeks after taking office, David Cameron sent a letter to all government departments demanding that they "open up" data. "Greater transparency across government," he wrote, "is at the heart of our shared commitment to enable the public to hold politicians and public bodies to account; to reduce the deficit... and to realise significant economic benefits by enabling businesses and non-profit organisations to build innovative applications and websites using public data."

Among the commitments the prime minister made was the promise to publish online: all "new items of central government spending over £25,000" from November this year; "full information on all DFID international-



04 LONDON CONGESTION CHARGE / 2008

These maps compare (*from top*) car, motorbike and bicycle use in London between 2001 and 2008. Red indicates a fall in traffic, blue a rise. Congestion charging (*zone in yellow*) reduced motor-vehicle use across the city.

development projects over £500" from January 2011; and, within the same timescale, crime data "at a level that allows the public to see what is happening on their streets".

Street-level searchable data maps and charts are increasingly popular in the US. City-data.com, which claimed 15 million unique visitors in March 2010, allows users to search cities with 6,000 residents or more for data ranging from population density and racial make-up to the number of registered sex offenders and building permits issued for "single-family new houses".

Meanwhile, Oakland Crimespotting, a crime map of Oakland, California, updated daily from police reports, has shown how data can be useful at a neighbourhood level. As well as providing an online map, the site allows residents to sign up for email alerts and RSS feeds, and functions as a browsable crime database.

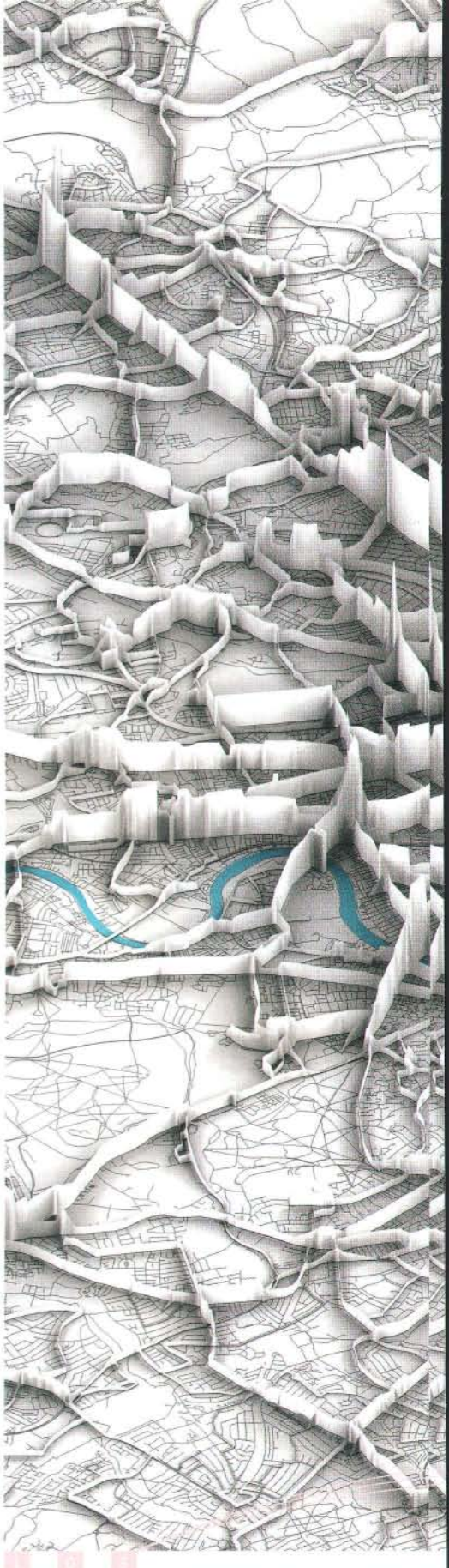
In the UK, the process of letting daylight seep into previously guarded public data began under Gordon Brown, who, in 2009, asked Tim Berners-Lee, the computer scientist credited with creating the web, what could be done to make better use of the internet. Berners-Lee's much-quoted response – "Put all your government data on to the web" – set in motion a chain of events that culminated in the launch, in January 2010, of data.gov.uk. With access to a deluge of government-held non-personal data, developers could now create apps, mashups and visualisations. Its far bigger US equivalent, data.gov, launched in May 2009, now offers 272,677 datasets for reuse, with 236 applications already built.

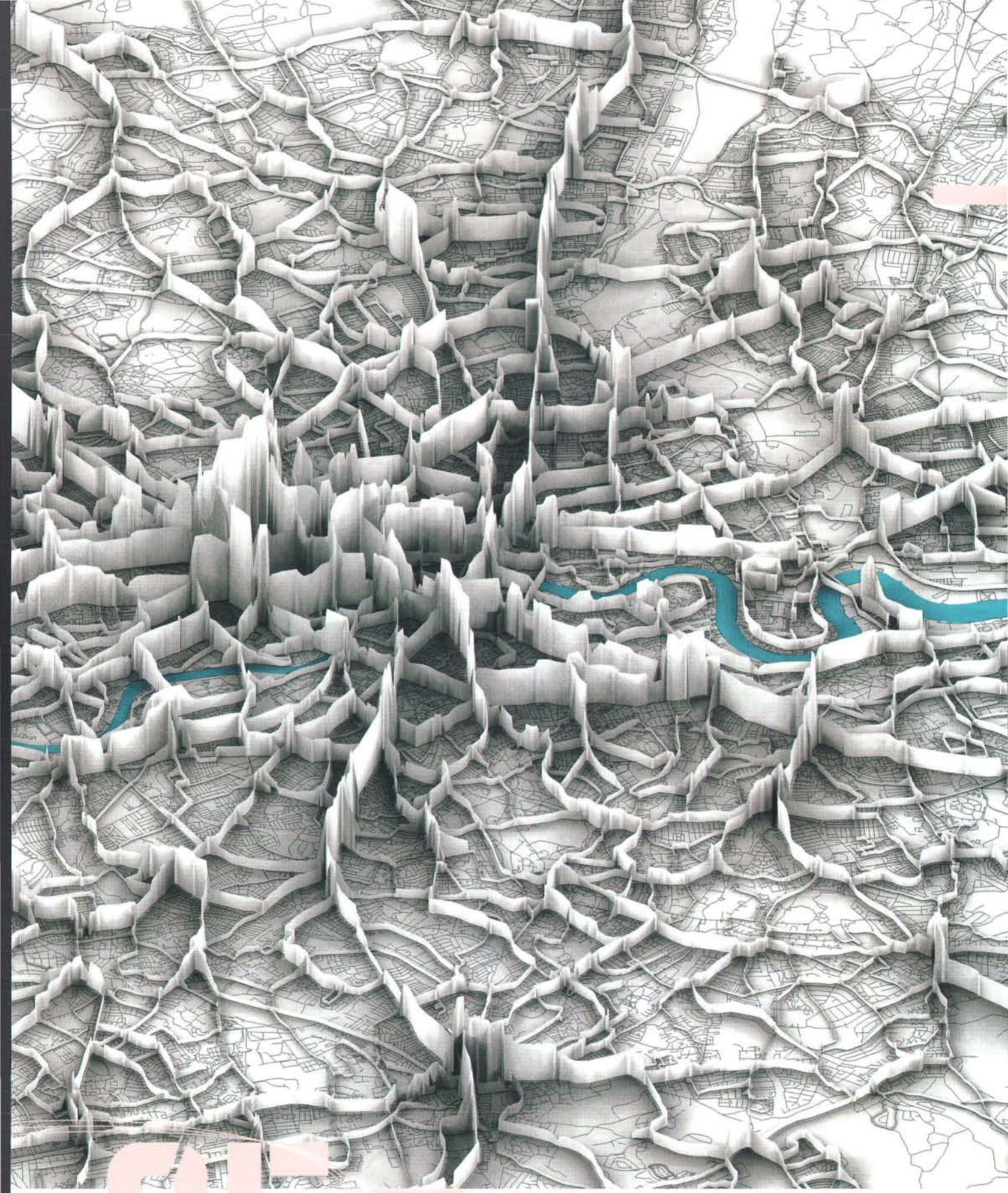
Whether it is searchable crime maps or real-time trip-planner apps, the freeing up of government information has brought about a data revolution, shaking up existing models and changing lives.

At the Institute of Medicine in Washington DC in June, developers unveiled 16 projects which aimed to "harness the power of information to improve health". Among them was a web portal built by the Network of Care for Healthy Communities in Sonoma County, California, a health-advocacy organisation. By aggregating government data into a community dashboard, the site helps decision-makers design effective and trackable health policy.

This data-led, web-inspired movement – branded Health 2.0 or open medicine – is boosting patient-power too. Network for Care's portal lets patients choose practitioners. PatientsLikeMe is a free data-sharing social-networking platform on which 70,000 registered users share information and "real world, outcome-based patient data", on conditions from MS to HIV and depression.

"We're giving patients the power to collect information to help them manage their





LONDON BUS FREQUENCY / 2009

The central peaks and low trails coming out of London on this map represent the frequency of buses in each location – with height showing the number of buses passing a point in a 24-hour period in autumn 2009. ITO created the visualisation to help route-planners. The southern cluster is Croydon.

MINSK / 2009

Because OSM relies on individual volunteers, particular areas sometimes feature idiosyncrasies. This OSM map shows the painstaking mapping by one contributor of individual building outlines in Minsk. Another volunteer is logging all the electricity pylons in East Anglia.

illness," says PatientsLikeMe cofounder and chairman Jamie Heywood. "We build a data-framework model of a disease, and let patients fill it in." Data gathered on the site is put to valuable use, he says. "We've done clinical-trial recruiting and collaborations with academia, and we sell pharmaceutical companies information and services."

The deaths of 400 patients at Stafford Hospital, 50km north-west of Birmingham, between 2005 and 2008 is now the subject of a public inquiry. But the revelation that patients had died unnecessarily after undergoing treatment at the hospital might not have been picked up at all were it not for data gathered by medical-intelligence company Dr Foster. Using NHS-derived datasets, it found that the hospital had overly high mortality rates, which prompted a full investigation.

The tale of a company which set out to gather, analyse and repackage government data – and now provides intelligence back to the NHS – is an inspirational one to Christopher Osborne, business-development director at transport-technology company ITO, which provided the visuals on these pages. "[What Dr Foster] did is very similar to our mission to provide transport intelligence to government," he says. But ITO – which offers "web-based services... using state-of-the-art visual-effects techniques" – is up against a formidable obstacle: namely, the fact that the open-data revolution has yet to impact significantly upon the UK's public-private transport system.

"It's a sorry state of affairs," sighs Osborne. "There's so little transport data out there. And there hasn't been much discussion about it. This country is currently trying to make huge transport decisions – High Speed Rail 2 involves a minimum of £20 billion – but we're doing it without data about how people actually use transport. We just make educated guesses at it."

To inform such decisions, ITO has been working on Ideas in Transit, a five-year research project. "We're trying to step back from large-scale, top-down transport projects to ask how we apply user innovation to transport. Very quickly it emerged that there's a thriving developer community out there for transport, but it's totally reliant on access to data." Osborne contrasts the situation with the US, where dozens of public-transport-related apps have sprung up, using data from the 113 transit authorities whose "open" policies allow developers to reuse their information. "We don't have that ecosystem yet in the UK because most of the data is still locked away," he says.

The situation in Britain is changing, however. In mid June, Transport for London (TfL), the body which runs most of London's public transport system, lifted its restrictions on the commercial reuse

OPEN-DATA MASHUPS IN ACTION

FLIGHT RADAR24.COM

When an Icelandic volcano which had been dormant since 1823 erupted on April 14 2010, sending a plume of ash into the atmosphere, swathes of European airspace were closed for seven days. At the height of the crisis – on April 18 – there were just 5,204 flights in Europe, compared with 24,965 on the same day a week earlier.

Overnight, Eyjafjallajökull's angry ejections transformed flight-data-and-map mashup Flightradar24.com (FR24), which tracks live air traffic, from geek-zone online curiosity to the go-to site for stranded passengers searching for data with which to plan their routes home.

FR24's visualisation (*below*) – clickable yellow planes, with coloured trails signifying altitude – brought the crisis to life. "Before the ash cloud we used to have between 50,000 and 70,000 visitors a day," says Mikael Robertsson, the site's Stockholm-based creator. "[During the flight ban] we were suddenly attracting one million a day."

FR24 works by tracking the progress of aircraft fitted with ADS-B transponders (about 60 per cent of passenger aircraft, including all models of Airbus planes, Boeing 737-787 series and some series of Fokker, Gulfstream and McDonnell Douglas jets), via a network of people with ADS-B receivers around Europe. "[People who want to join the network] send us an email and we send them a small script/software that they run on their local computer," explains Robertsson.

From IP addresses in FR24's log-files, Robertsson knows that many of the site's visitors are from airlines, including SAS, Lufthansa, Norwegian, Finnair, airBaltic, Air France and BA. "We also know that airport employees are using FR24 to know when planes will arrive," he says. A small Google AdSense banner covers "almost 100 per cent" of the running costs. JS

ASTHMAPOLIS

As a frontline scientist with the Atlanta-based US Centers for Disease Control (CDC), David Van Sickle was part of a team of epidemiologists called in to investigate unusual outbreaks of disease. But there was one disease Van Sickle never got to investigate during his time with the agency – asthma. "That was pretty startling," he says, "when you think it's one of the most common chronic diseases.".

When he left the CDC, Van Sickle began asking what had prevented the team from investigating asthma. He came to the conclusion that the omission was due to the poor quality of public-health surveillance data. "The data we had was focused mainly on hospitalisations and death, which we often got years after those had occurred, so it was neither timely nor geographically specific." In response, he developed Asthmapolis – a data-gathering and disease-mapping project (*below*).

There are two main strands to Asthmapolis. The first is a project that tracks the conditions in which asthma patients develop symptoms, by attaching a device known as a SpiroScout to their inhalers. This uses GPS to ascertain where and when an inhaler is used and sends this data to a remote server. A second project uses web-enabled mobile phones to map and track symptoms, triggers and the use of inhalers and other medications in a digital diary. The Asthmapolis website then summarises patterns of use and trends over time, with maps, tables and charts.

"We then try to identify what we can – based on other things we collect such as activity patterns, data from individuals about where they work, their job, where they live." Van Sickle says the studies have been revelatory about when and where people have asthma symptoms. "Whereas public health has often focused on exposures within the home – dust mites and pet dander [flakes of skin] – we discovered that patients were more often using their inhalers in other locations such as at school or in town," he says. "We've also seen interesting data patterns in the time of day when asthma occurs." JS

CITY-GO-ROUND

Real-time bus updates; personalised "walkability mapping"; real-estate searches by transit stop – these are just three of the 132 mobile apps on the US site City-Go-Round.

Launched last December, the site is a pocket revolution of local-transport apps which use open data from the 113 transit agencies to have released their information to date. "We think that great software is one of the easiest ways to make public transit better to ride and more efficient," says Matt Lerner, chief technology officer at Front Seat, a "civic software company". "In Seattle, where I live, there's an app called *One Bus Away* (*above*) that tells you exactly when the next bus will arrive, so you don't have to wait at the stop for 20 minutes."

The transit agencies – including a handful in Canada and Australia – make their data available in General Transit Feed Specification, a format that was created by Google specifically for transit information. "This has become the standard format for transit data and is easy for programmers to work with," says Lerner, a former lead programme manager for Windows Vista at Microsoft. Data from City-Go-Round is currently viewed by over one million unique visitors per month on its sister site Walk Score – a popular site which calculates the "walkability" of any address. JS

of its data by software developers, as well as releasing several new datasets including feeds from live travel news and departure boards. By July 1, one of these, the London Underground departure-board feed, which gives live train information, had had to be withdrawn after receiving more than ten million hits per week. As WIRED went to press TfL was unable to say when the feed might be reopened.

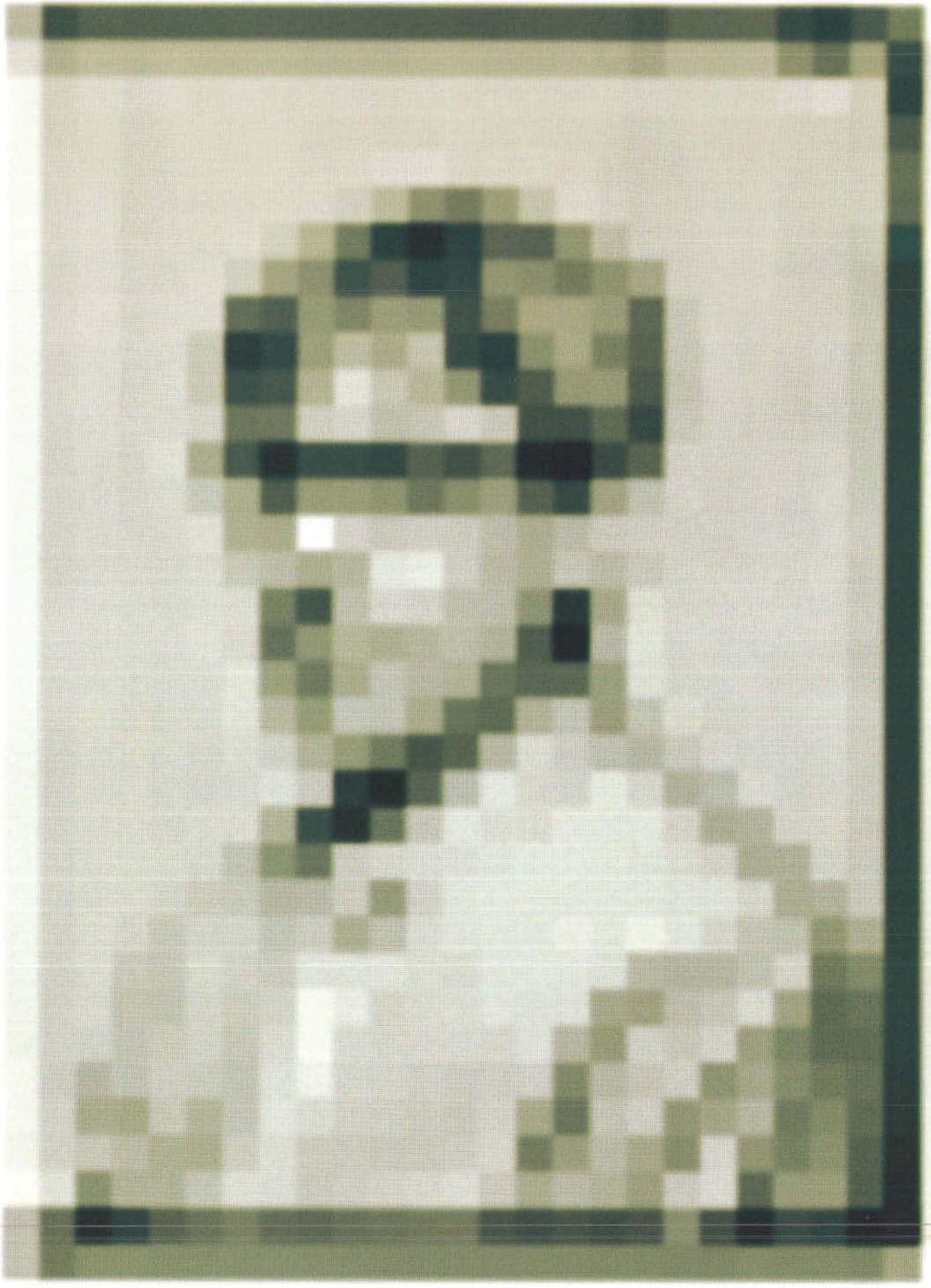
That aside, Jonathan Raper, professor of geographic information science at City University and advisory-committee member of the London Datastore, which supplies data sets from the Greater London Authority, says future releases will be even more meaningful and could include anonymised travel-pattern data derived from RFID-enabled Oyster cards. "That's absolutely on our agenda. It's accepted by TfL that Oyster data will be released." (TfL says there are currently no plans to release Oyster-related data.)

Revealing real-time usage data from transport networks would certainly help in determining, say, when and where to run more trains. Traffic-count data sets released by data.gov.uk – which is gathered by people counting vehicle flow with clickers for one day a year – enabled ITO to create a UK traffic "heat map" of the years between 2001 and 2008. "In that time, the numbers of cars increased across the UK," explains Osborne. "But if you look at the traffic count between those years there's little change – apart from in London."

In the capital, the visualisation – a cluster of multicoloured dots – thins out over the seven-year period (*see previous spread*). "The data shows that the most successful scheme in UK transport in the past ten years was London's Congestion Charge. When you go through the data and do some clear visualisations, you can see that there's been a huge decrease in the cars-and-taxis category right across London."

From better-informed government decision-making to software developers building apps, the digital age is rewiring daily life. With raw public data freeing up, Berners-Lee, the man who kick-started the UK government's open-data revolution, hopes the momentum will now be "self-driving". Next he plans to push to free up other datasets. "What should it be in 2010?" he asked earlier this year. "Putting government data on the web has been a very exciting journey. We have to keep pushing, though." W

James Silver wrote about the trust economy in our 06.10 issue



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Previous pages: how Greenberg says this spread would look to a patient fitted with the implant

Vision of the future

8.5

After 12 years in the lab, Robert Greenberg has brought a viable retinal prosthesis to market – and returned at least some visual acuity to sightless patients. The bionic eye has finally arrived. By Duncan Graham-Rowe. Photography: Spencer Lowell

June, 2010. Deep within the airy, new building that's home to the Manchester Royal Eye Hospital, a well-built 52-year-old man with short, fair hair sits in a darkened room. He faces a computer screen, although the dark glasses he's wearing make it impossible to tell whether he's looking at it. A shape appears onscreen and, as it does so, John Rose (not his real name) begins to move his head almost mechanically from left to right and back again. After a few moments he calls out: "Triangle." Another shape appears. His head scans, left to right, left to right. "Circle," he says. Next a large letter – 22 centimetres high – appears before him. Rose's head sweeps back and forth across the screen before he reads it out. More letters come, then words. Then smaller letters and smaller words, until they are just a few centimetres high.

As eye tests go, this may not seem remarkable, even taking into account the hindrance of the shades. But what makes this exercise truly extraordinary is that this man has no visual perception – his eyes do not function. Without the glasses and the movement of his head, he would be completely blind.

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Rose, a former surgical technician who wishes to remain anonymous, began losing his vision in his twenties and, besides some limited light perception, has been clinically blind for the last seven years. But he is one of the first of a few dozen people to have received a transformational new eye implant that has restored a limited amount of his vision. Rose's retinal prosthesis receives images fed to it from a tiny camera mounted within the glasses. His head movements help to improve the quality of what he sees by allowing him to take in more of his surroundings by increasing his field of vision. "I can see letters and three- or four-letter words," he says. "I hadn't seen these things for years, so the chance to see them again is amazing."

This implant, the Argus II, is a fully functional commercial product. By the end of this year, the regulatory paperwork will have been processed and the device is expected to have received clinical approval in Europe, making it the first retinal prosthesis to come to market. The age of the bionic eye, it seems, is finally upon us.

The level of vision the Argus II offers is still far short of that

Robert Greenberg, cofounder, president and CEO of Second Sight, the California company that developed the Argus II

which sighted people experience, producing just 60 dots of light in the field of vision, compared to the 120 million or so produced in a healthy eye. Nevertheless, in trials Argus II patients have all identified some benefits. For some it allows them to make out basic shapes, so they can see where people are when talking to them, or navigate through doorways; others can even shoot basketball hoops, sort laundry and, in some cases, such as Rose's, read print.

The principle behind the device has long been known: gently zap the retina using an electrode with microamps of current, and it's possible to replace the function of damaged light-sensing photoreceptor cells. Stimulate the remaining healthy nerve cells in the retina, and sensations of light can be created in the visual field. Zap enough cells, and images start to take shape.

The effort has been demonstrated numerous times over the past three decades in animals and on humans under local anaesthesia in surgical conditions. Doctors such as Eberhart Zrenner, director of the Institute for Ophthalmic Research at the University of Tübingen in Germany, have taken this further. In 2007, Zrenner carried out 11 so-called "acute implantations" whereby the device is implanted in the patient's eye for a relatively brief period of three months before being removed again. But, until recently, researchers hadn't designed a device that could be left permanently implanted in the body.

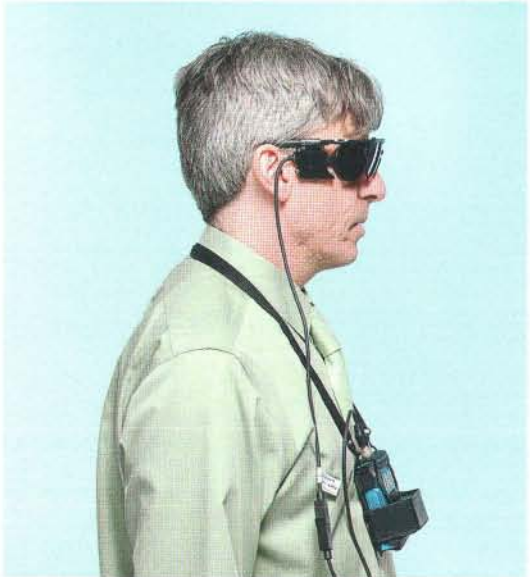
obert Greenberg, 42, cofounder, president and CEO of Second Sight, the Sylmar, California-based company that developed the Argus II, knows how hard it is to build a prototype that can be placed in the eye, even temporarily. The harsh saline environment of the human body is as corrosive as the sea: if you leave an acute implant in for too long, the body will destroy it. "Creating a device that can be implanted permanently is like building a television set that you can throw into the ocean and will still work, and continue to work for another 20 years," Greenberg says.

For Second Sight to restore vision to the blind it took years of innovative engineering, tens of millions of dollars of investment, a dash of rocket science and a deep sense of purpose – not just the kind motivated by financial profit, but also that driven by the promise of profound personal reward for someone with nothing to lose and everything to gain. Like many great ideas, the Argus II began with the coming together of two minds. Sitting in his holiday home near North Fork, in the southern part of California's Yosemite mountains, Greenberg, 42, recalls that first meeting in 1998. Greenberg – a qualified biomedical engineer and medical doctor trained at Johns Hopkins Medical School in Baltimore – was working for the Alfred Mann Foundation, a California-based non-profit medical research group. There he had helped develop one of the first cochlear implants, devices that help hundreds of thousands of clinically deaf people to hear.

The success of the implant had prompted one of its investors, Sam Williams, to approach Greenberg's boss, Alfred Mann, to ask if a similar device could be developed for the eye. Williams, then 77, was a talented and highly successful engineer and philanthropist who had made his fortune designing miniature engines for private jets and Tomahawk cruise missiles. It was a Williams jet that was to help SpaceShipOne win the $10 million X Prize in 2004 when it became the first private spacecraft to go beyond the stratosphere. Three years before his meeting with Greenberg, Sam Williams had been awarded the US's National Medal of Technology and Innovation – other recipients of which have included Steve Jobs and Bill Gates.

Knowing that Greenberg had spent six years carrying out research in retinal prostheses as part of his PhD at Johns Hopkins between 1991 and 1997, Mann had called a meeting to bring the two together in Palm Springs. Greenberg arrived at Williams's home and was stunned by the view of the valley below. He made his pitch, outlining his earlier research on retinal cell-stimulation. "I talked about the work I had done at Johns Hopkins, I talked about some of the ideas I had at that point and what I'd like to do to take the research to the next step," Greenberg recalls. "Sam was an impressive man with broad technical knowledge. I remember being surprised by how quickly he grasped the issues we would have to tackle to build a successful retinal prosthesis." Greenberg finished talking. Now it was Williams's turn.

His proposal was nothing short of outrageous: Williams, a multimillionaire, wanted to bankroll Greenberg



***Above*: a model of a human eye-socket, from Greenberg's desk. *Left*: Greenberg and the Argus II's non-implanted components**

to develop a commercially available cure for blindness. (Greenberg won't reveal the scale of Williams's investment.) And he needed it done yesterday. "He wanted this to happen in his lifetime," Greenberg says.

Williams's demands were audacious, but Greenberg didn't doubt his sincerity for a moment. For all Williams's fortune and success, Greenberg knew that the picturesque view no longer held an allure for the engineer: Williams, a victim of the degenerative eye disease retinitis pigmentosa, was blind.

Keen to find a way to restore his own sight, Williams had previously funded university research into retinal prostheses but had grown frustrated by the slow progress. He had come to believe that the only way to speed up development was by making the search for a cure a commercial endeavour. "Sam was adamant about setting up a separate company," Greenberg says. "As an entrepreneur he thought that it was important to engage the employees with stock options and give them a focused incentive to produce a device. He felt that this would be a more productive way of approaching the project, and I think he was right."

And, in Greenberg, Williams had found the right man for the job. Not just because of Greenberg's entrepreneurial streak (he had developed and sold software programs and medical devices even when still at high school). Nor was it Greenberg's biomedical-engineering expertise. What Greenberg brought to the table was a passion that matched Williams's drive. Long before their meeting, Greenberg had already made the decision to devote his professional life to making retinal prostheses a reality.

In 1991, while at Johns Hopkins Medical School, Greenberg had been given the rare opportunity to join pioneering retinal surgeon Eugene de Juan in carrying out some of the first experiments in stimulating the retinas of blind patients. "This patient first had one electrode put into his eye, and when the technician turned on the electronics he saw a spot of light. Then Eugene put in two electrodes, alternately flipping on one electrode or two, and the patient would either see one spot of light or two," Greenberg says. "At that point I was hooked. It was pretty obvious at that moment, at least in my mind, that it was going to be possible to create a prosthesis for the blind."

With funding from Williams, Mann and two other investors, Second Sight was set up in a matter of months. Greenberg was its first employee, and his former mentor, de Juan, and biomedical engineer Mark Humayun, then also at Johns Hopkins but now associate director of the Doheny Eye Institute at the University of Southern California, were brought in as consultants. "I spent the spent the first six months travelling around the world and hiring the best research team I could find," Greenberg says.

From the outset, Second Sight's approach was to focus on how to make a device suitable for chronic implantation. Greenberg was aware of the rigorous testing and scrutiny a device would have to undergo: in 1997 he had spent nine months working for the US Food And Drugs Administration, the formidable agency responsible for giving clinical approval to medical devices. So Greenberg knew only too well that in addition to the challenges he faced in building a chronic implant, if it was ever to make it to market, what lay ahead was

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bench-testing, animal trials and clinical trials to prove the device's longevity, safety and functionality.

A retinal prosthesis is made up of three main components. An external unit captures and processes images from a camera and feeds them to a second component within the body which translates these signals into electrical stimulations. These are then fed to the third component, an array of electrodes that sit either behind or in front of the retina. As a proof of principle the decision was made early on to use existing technology wherever possible, and in particular to borrow the tech used in cochlear implants. "With our first system, the Argus I, we essentially took a cochlear implant developed by our sister company, Advanced Bionics, and put a different electrode array on it," Greenberg says.

Adapting electronics designed for audio processing to handle video signals may sound an unconventional approach, but there were sound scientific principles behind the decision. The Alfred Mann foundation had already invested $50 million to develop these chronically implantable devices and they were already approved for clinical use. With the clock ticking, it would save time as well as money. These devices had a wireless means of getting the signals from the external unit to the processor inside the head by using an induction loop. This also provided a convenient way of powering the internal device without having wires leave the body.

But that still left the delicate task of developing the electrode array. "I expected that to be a six-month project – but it took a couple of years," Greenberg says. The retina resembles a wet and very delicate piece of one-ply tissue paper. So the challenge was to make an interface that could be placed close enough for the electrodes to stimulate the underlying nerve cells, but without damaging the retina.

For Greenberg (*right*), developing the Argus II device was "a truly monumental, world-changing leap in the neural prosthesis field"

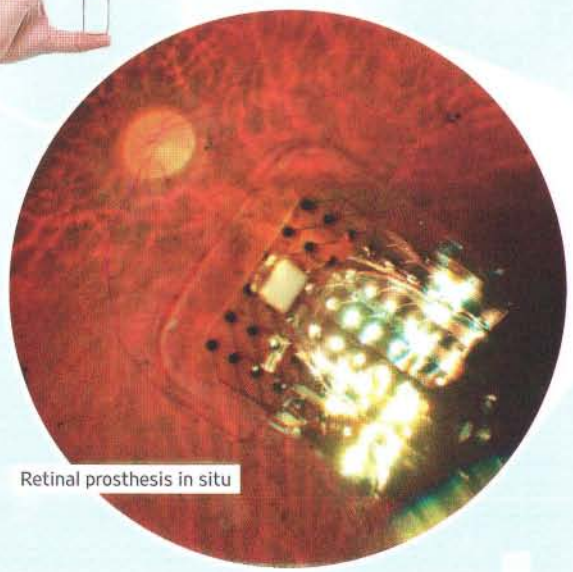
To do this the interface has to be almost as pliable as the tissue, so that it will conform to its shape. This ensures that each electrode sits as close to its target nerves as possible. Adding to this complexity, the device also has to be completely sealed to protect it from bodily fluids and yet allow the electrodes to protrude without causing leaks.

With the help of a $25 million grant from the US National Institutes of Health, Greenberg says, in 2000 Second Sight eventually managed to solve these issues, although he won't reveal how. But he says it was problems like this that consumed a large part of company development time and resulted in Second Sight notching up around 100 patents for everything from techniques for biocompatability bonding and encasing the electrodes, to motion compensation techniques for the video capture and signal processing for the video feed.

During this period Williams was ever present, impatiently urging on the researchers. "He wasn't the only one, we had other investors breathing down our necks," Greenberg says. But Williams was different: his engineering expertise was invaluable. On paper he may have been just one of the company's board members, but, according to Greenberg, he was highly involved in the research. "In the early days, he and I spoke often about technological issues that we were facing. Sam was a great sounding board and many times helped me think through the design challenges," Greenberg says. In developing the electrodes, some of the toughest challenges demanded answers from material science, such as finding ways to miniaturise metal and ceramic components. Given that Williams had built his career on taking large objects, such as jet engines, and then making them smaller, his insight was invaluable. "He had a lot of input about how we might solve these problems," he says.

The Argus II inside your eye

Implant



Retinal prosthesis in situ

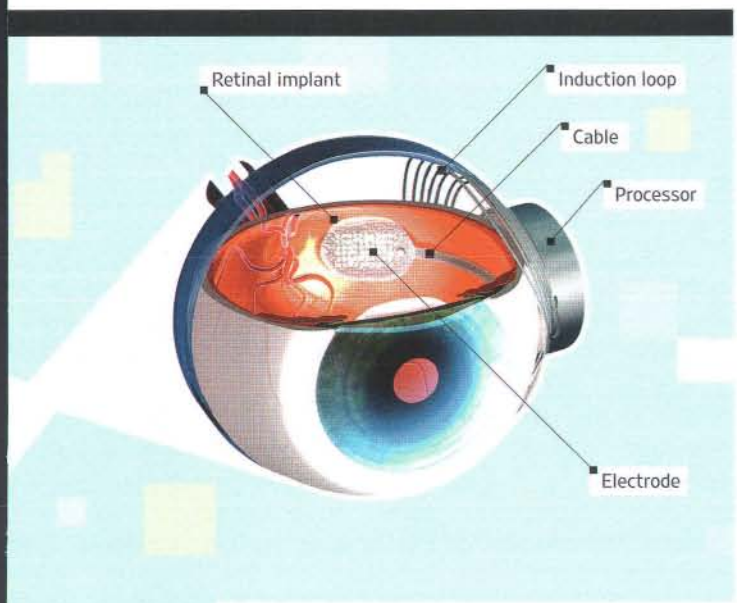
After extensive bench testing and animal trials, the team was ready to begin its human implantations in 2002. The first Argus I patient was a 74-year-old retired concession-stand vendor from Maryland. "He was actually the first to volunteer for the intra-operative studies at Johns Hopkins many years earlier," Greenberg says. "At some point, he was told that if we ever had a long-term implant, he would be the first to receive it. It was very gratifying to have been able to keep this pledge."

The procedure was a success and, between 2002 and 2005, six further patients received Argus I implants. Although a proof of principle with only 16 electrodes (one for each dot of light or pixel the patient would see), the implants worked better than expected, allowing patients to make out basic shapes and detect edges and lines. In part this was thanks to a behaviour the patients had developed as a result of their disease.

With retinitis pigmentosa – one of the biggest causes of blindness in the developed world, and the disease at which this technology was targeted – loss of vision is gradual. Patients increasingly experience tunnel vision until, eventually, they see nothing. During this process they often resort to "scanning" in order to see their environment. "If you look through a pinhole and move your head around, you can build up quite a high-res image of the world around you," Greenberg explains. "And that's what these patients were doing with the Argus I." With the camera mounted on the glasses, moving their heads enabled them to get a better resolution than the device alone offered.

In theory Second Sight could have applied for approval and gone to market with the Argus I. But, despite requests from patient groups to do so, the company still didn't feel the technology was ready. For one thing, the cochlear-implant processor they used had been discontinued. Secondly, the implantation procedure was complex, taking eight hours and requiring four of the world's top surgeons – Dennis Maceri, an LA-based ENT surgeon attached the cochlear implant; Michael Burnstine, then at the Doheny Eye Institute, California, ran the cable from the cochlear implant to the eye; and de Juan and Humayun attached the array inside the eye. If it was to become a widely available treatment, a simpler approach was needed.

As far as Williams was concerned, such an approach was just around the corner. From the beginning Second Sight had been working on a second-generation device. Rather than using a cochlear implant, this device (the Argus II) was to have a dedicated processor which could handle more channels, or electrodes (to boost the resolution) and which would simplify the surgery by being small enough to fit within the eye cavity.



The Argus II has a dedicated processor that fits in the eye-socket cavity. A biocompatible watertight casing sits on the outside of the eyeball holding electronics and circuitry. It allows the electrodes in the retinal array to be connected to it by a cable.

ut, much to Williams's frustration, the Argus II took several years longer to realise than anyone had anticipated. This, Greenberg says, was largely because it involved such an enormous challenge: the equivalent of taking a device as complex as a pacemaker and shrinking it down to the size of an aspirin. "That was a truly monumental, world-changing leap in the neural-prosthesis field," he says. It involved miniaturising all the electronics and circuitry within a biocompatible watertight casing that would sit within the eye cavity on the outside of the eyeball. Simultaneously this had to allow each of the electrodes in the retinal array to be connected to it by a separate cable, again without any risk of seepage. "It went through several iterations before we arrived at the present design," Greenberg says. But what they ended up with made it possible to implant the device in just a few hours with only one surgeon.

In September 2006, a woman (Second Sight will not reveal her identity) in Mexico was the first to receive the device. Today there are 29 people around the world, including John Rose, who have had some of their vision restored thanks to this new implant. The 60 electrodes offer considerably better resolution than the 16 of its predecessor but, according to Rose, are still a long way from restoring full vision. Rose, who started to lose his sight back in his 20s and has been completely blind (with only limited light perception) for the last seven years,

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3 received his Argus II in June 2009. After a two-month period to let the implant bed in, it was switched on. At first, Rose was disappointed. "I was probably expecting to see more," he says, citing overly high expectations.

Initially the team just tested the electrodes, turning them on sequentially. "It was very obvious when they came on," he says. He would see yellowish-white balls of cotton shimmering in his field of vision. Following this, his surgeon Paulo Stanga, associate professor of ophthalmology at the University of Manchester, started to create shapes using the electrodes and eventually turned on the camera. "There has to be a lot of light about," Rose says, but he can make out objects and has since shown that in high-contrast conditions he can make out shapes appearing on a computer screen. And with training, to help his brain adapt, he has since learned to recognise letters and words.

Rose still uses his walking cane for guidance, but says the implant helps him in daily life. "I use it getting around my flat, going through doors," he says. "I can see where chairs are. You can't always make out what something is, but you can see that there's something there, the TV and a picture on the wall. I can't see the picture, but I see its outline." Rose suffers confusion outside home because there is too much visual information for him to make sense of images, and it's hard to tell if something is near or far. "But when I look out
1.8 the window I can see the cars on the road below."

tanga says that it's a significant improvement on Rose's former vision: in clinical terms it's the equivalent of a two-category improvement, giving Rose the kind of vision he would have had about 15 years ago. "You have to bear in mind that retinitis pigmentosa has no treatment, so such an improvement is dramatic," Stanga says. "Until now, his vision would only get worse."

And, with Second Sight planning on developing devices with larger numbers of electrodes, the technology is likely to improve. During the development of Argus II, the company experimented with thousand-plus electrode arrays. But making such devices suitable for lifelong chronic implantation is incredibly difficult, Greenberg says. In the end it comes down to a trade-off: adding electrodes means increasing the number of
1.2.0 individual wires connecting the internal processor to the array; keep adding them and pretty soon the device becomes bulky, unwieldy and increases the chances of seepage or something else going wrong. The way Greenberg sees it, Second Sight could have spent years trying to improve the resolution, or it could bring the benefits of partial sight to market now.

It's a roadmap modelled on the first cochlear implants. These had just one channel, enabling implantees to hear either sound, or no sound. With the Argus II, the aim is to provide patients with limited vision to assist them with navigation and orientation. Techniques like multiplexing – whereby multiple signals are sent down a single cable – will contribute to improvements, Greenberg says, although even cochlear implants are only just beginning to do this. There are also ways to produce sub-pixel stimulation of retinal nerve cells, by using pairs of neighbouring electrodes to address cells that lie between them.

Other groups are pursuing Second Sight's market with very different approaches. Zrenner's company, Retina Implant AG, which was founded in 2003 near Tübingen, has a device which needs no camera, but instead uses the eye's working components to focus light on an array of electrodes behind the retina, each with its own light sensor. The device still requires a power supply similar to those for cochlear implants to boost the signal, but Zrenner says it removes the need for a patient to have to scan his or her head. And, because it doesn't require the electrode array to be connected to a separate processor via lots of tiny cables, Zrenner's chip has 1,500 electrodes – which potentially offer greater resolution.

Although Zrenner is upbeat about the trials in the 11 patients who have undergone the procedure, saying that one can even read print, Stanga is not so convinced. "At this point the results of devices with a larger number of electrodes are disappointing," he says. According to Stanga, only one of the patients with a 1,500-electrode device experienced an improvement in vision on a par with the seven best Argus II recipients. And, since they were implanted temporarily, the long-term clinical benefits remain unclear. In Stanga's opinion, the best improvements will come from improved signal processing and software, not necessarily an increase in the number of electrodes. Zrenner counters: "Argus II requires continuous and rapid head shaking to refresh the percept mediated by 60 electrodes, but the last three patients in our study perceived images continuously in a natural way. This is clearly a unique, huge qualitative difference."

If Zrenner is able to establish long-term clinical benefits, his approach may prove to be the way forward. That is because, unlike Second Sight's approach, Zrenner's allows the number of electrodes to be increased without increasing the number of wires.

Regardless of which technology prevails, the arrival of the Argus II on the market will be an important milestone, Zrenner says. The clinical benefits may now seem limited, but the technology has arrived. "The Wright brothers showed flying was possible," Zrenner says. "They first flew just 37 metres but showed the principle even though it would take another quarter of a century before Lindbergh crossed the Atlantic." Today, technology moves faster: within three to five years Zrenner hopes to have a 1,500-electrode device on the market.

Left: a technician in Second Sight's clean room. This is where assembly of the implant portion of each Argus II is completed

As well as improved resolution there is the distant possibility of colour. Argus II patients tend to see in monochrome, or at least a yellow version of it. The retina contains more red and green light receptors than blue ones; stimulating them indiscriminately creates a yellowish-white effect. Greenberg says that in the long term the potential is there to target these nerves more precisely and produce colour images.

John Wyatt, an electrical engineer at MIT who is cofounder of the Boston Retinal Implant Project, a collaboration between the Massachusetts Eye and Ear Infirmary, Harvard Medical School and MIT to create engineering solutions to treat blindness, says better vision is likely to be achieved, but he is doubtful that full-colour vision will ever be possible. Currently, electrodes are relatively large compared to their target cells, so with each zap hundreds, if not thousands, of cells are stimulated simultaneously. To allow full vision the electrodes would have to stimulate cells individually, which is a tall order. "It's like learning to play classical piano while wearing boxing gloves," Wyatt says.

But, as technology improves, genuinely useful vision should be achievable, he believes. What remains to be seen is how well the visual cortex learns to adapt to these electrode stimulations. The signals are not biological in nature, so when groups of neurons are stimulated simultaneously the brain needs to switch on some cells that should be off. Cochlear implants have shown that our brains can adapt to these artificial signals, Wyatt says, but with vision it's a lot more complicated.

Wyatt maintains that what Second Sight has done in developing the Argus II and making it fit for chronic implantation is a remarkable achievement. "It's engineering that no one else has been able to do," he says. And forming a private company helped to achieve this: Wyatt has received a similar amount to Second Sight in public funding, around $30 million, but the additional private funding that Second Sight has attracted – a figure Greenberg will not disclose – may have tipped the balance. And it's not just the money that has an impact on the research: investors will expect steady progress, Wyatt says. With around 200,000 people suffering from retinitis pigmentosa in the US and Europe, there should be a big enough market to support a private-sector approach.

Sadly for Williams, all this comes too late. He died last year, just 12 months short of having his dream fulfilled. Williams had remained active within the company until 2008, despite battling illness. He was aware of and excited by the progress the company was making and of how close its product was to market. And even though it became clear that the technology would arrive too late for him, the legacy he was leaving gave Williams a great sense of pride. "It was important to him even if he wasn't going to personally benefit from it," Greenberg says. "He was very proud that he had contributed to something so important."

Sitting on his sofa, staring out at the Yosemite mountains, Greenberg doesn't come across as a pioneer who has helped to cure blindness. He looks worn out from more than a decade devoted to a single end. It is as if he has been working so intently on his goal that he hardly recognises that he's achieved it.

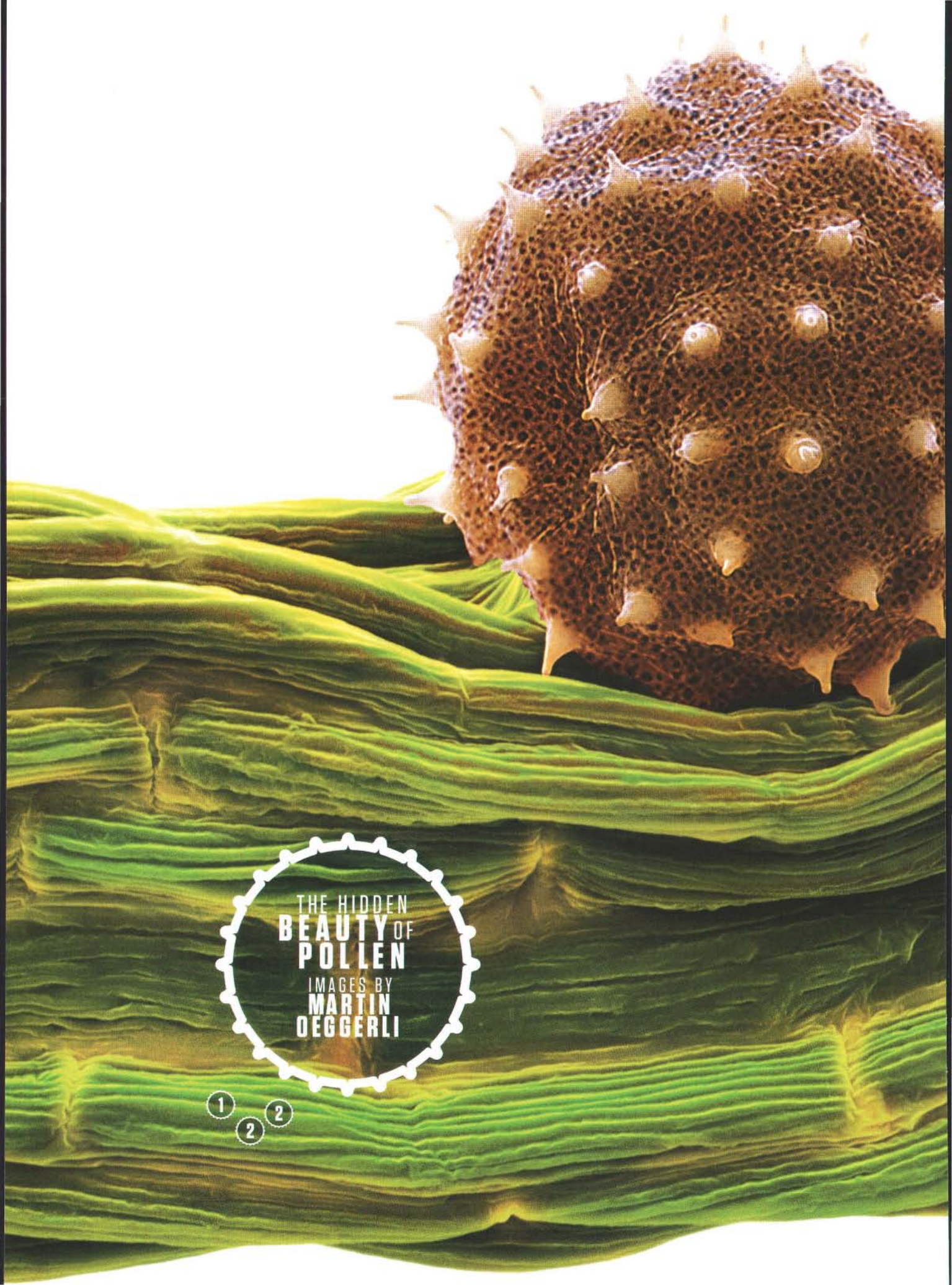
But, then again, Greenberg doesn't see this as a cure. "A cure would be to restore their normal vision. We're not on the threshold of a cure," he says. "But we *are* on the threshold of a new class of product that will allow these folks to get useful vision back."

Greenberg has every reason to be wary of boosterism. When the Argus II hits the market, initially in Europe, Second Sight expects to be inundated with patients desperate for the technology. Yet with a price tag of $100,000, it is likely only the very rich will benefit.

But it won't always be like that. When cochlear implants first came to market, they cost about the same as a retinal implant (when adjusted for inflation) – today, they are about $50,000. As government regulators begin to endorse the technology, Second Sight will gradually be able to increase its production of devices and training of surgeons, making it accessible to patients who may not be able to afford them privately.

And that was the ultimate aim of the work, Greenberg says: to get this technology out of the lab and make it available to patients. It may have taken them longer than planned, and it may be too late for Williams, but to turn it round in just 12 years is a remarkable achievement. "Sam would be very proud," Greenberg says. "He always had confidence that we were going to do it. And today I think he would be ecstatic to see that we have." ■

Duncan Graham-Rowe is a technology journalist based in Brighton and a WIRED *contributor*


THE HIDDEN
BEAUTY OF
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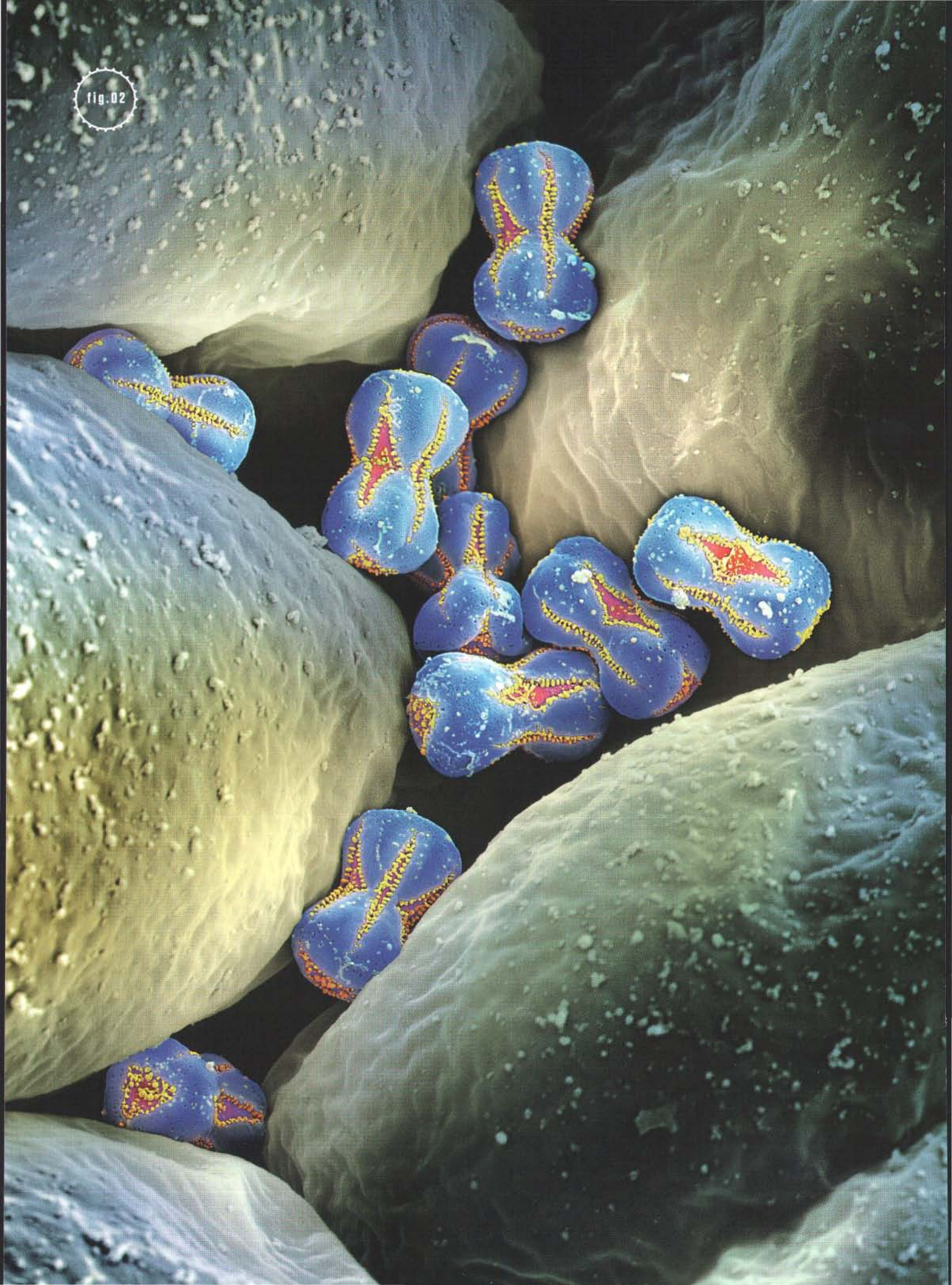
IT'S A
SMALL
WORLD
fig.01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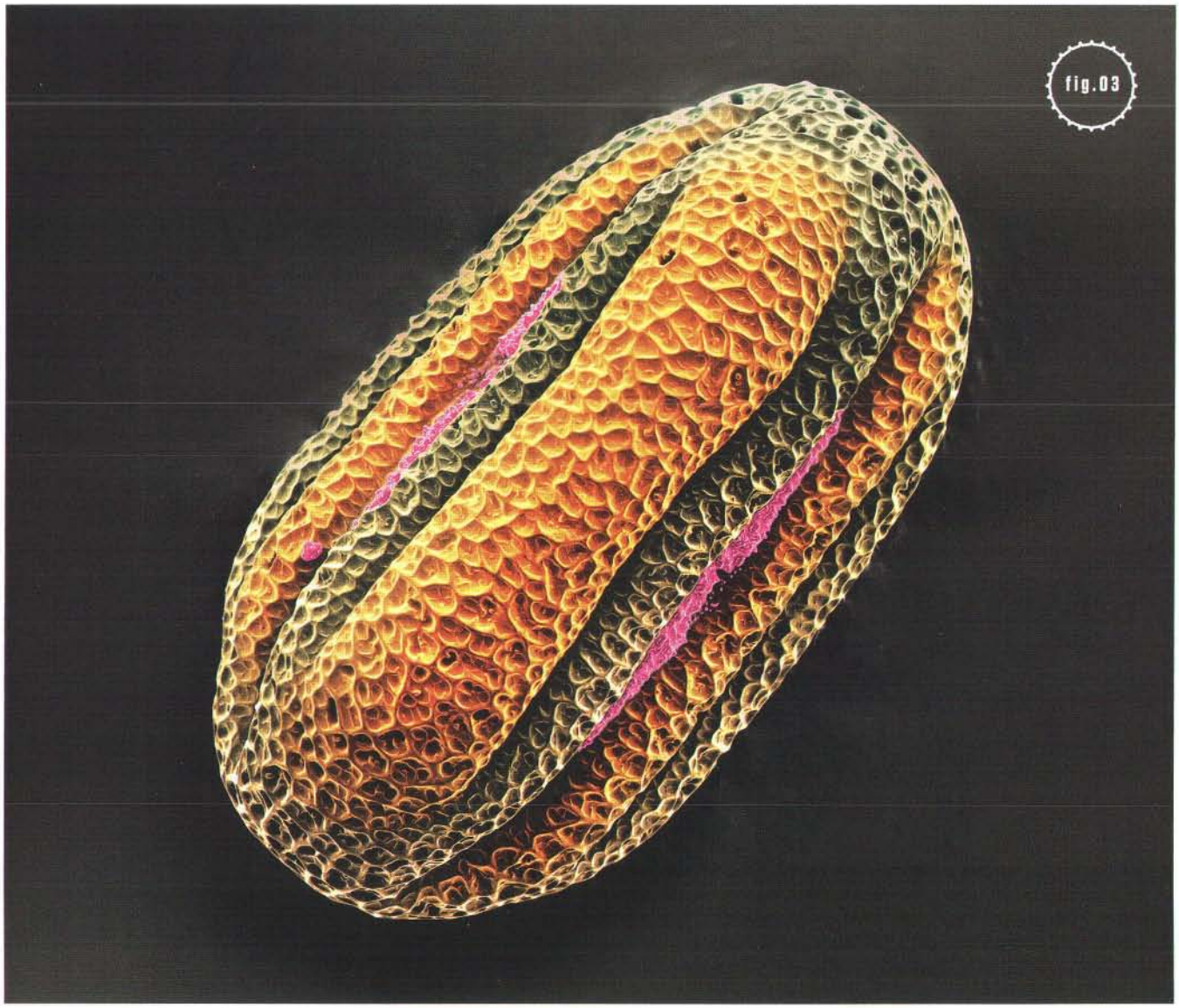


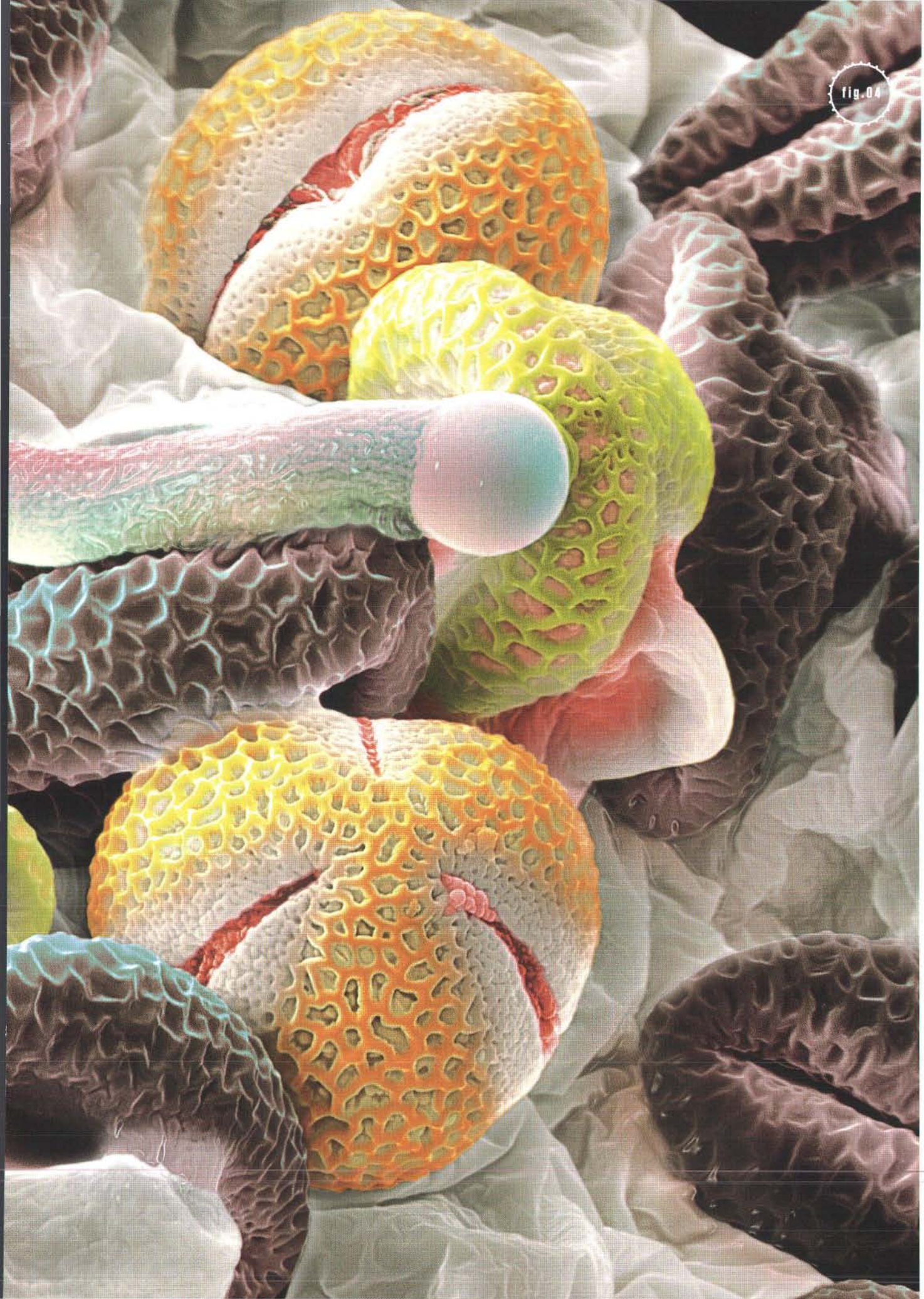
PHOTOGRAPHY: OLIVIER T GIGER

Martin Oeggerli, aka "The Micronaut", is a Swiss scientific photographer who captures images of nature's smallest structures – from insect eyes to cancer cells, and on these pages tiny pollen specimens. His scanning electron microscope produces magnification of up to 500,000:1 – compared with 2,000:1 for a standard light microscope.

It works using electron beams to scan the sample, and thus requires the materials to be conductive – so Oeggerli coats each with gold. "Our machine produces a high vacuum and spots specimens with a thin gold layer on them," he explains. "This shouldn't be visible, not even underneath the microscope. But this is the compromise: you need enough gold to make it conductive, but so it remains technically perfect."

Each shot can take anything from a few hours to several weeks to prepare, so as to bring out the detail in the smallest surface structures. The creative aspect is colourisation, which is 36-year-old Oeggerli's secret. His method has been developed intuitively, with no Photoshop involved.

"I use the colours of the flower the pollen is from," he says. "Not just for beauty, but to show something. Sometimes I'm capturing images to answer questions or visualise scientific results, but I also try to ask questions. For example, I make sure everybody notices the apertures where the pollen tubes grow. With the forget-me-nots, I highlighted the shape. Nobody knows the functions of the hourglass structures, so if I make people curious, one day someone will try to find out." **Jennifer Lucy Allan**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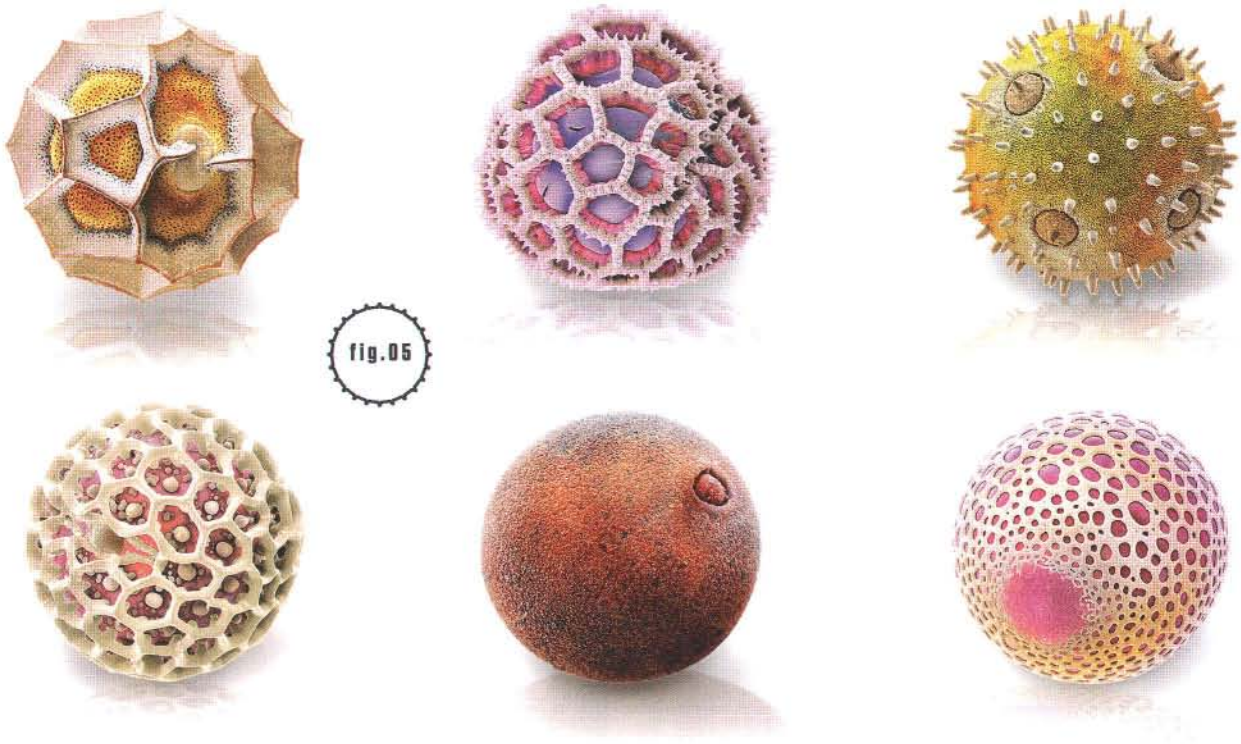


fig. 01

ABUTILON

Name of parent plant: Red vein Indian mallow
Size: 61.3 micrometres.
The pollen rests on a young leaf of the plant, which is native to Brazil and Argentina. The surface of the pollen is covered with up to 100 spikes, so it attaches to animals, which carry out pollination. "Hummingbirds drink the nectar from this plant's cup-shaped flowers, which hang like lanterns," says Oeggerli. "The pollen drops down on the head and neck of the bird while it's feeding, and the spikes help it to stick."

fig. 02

MYOSOTIS

Name of parent plant: Forget-me-not
Size: 4.4 micrometres.
The forget-me-not has the smallest pollen in the world; each grain is an hourglass shape, although the most common pollen shape is spherical. "Forget-me-not pollen are about twice the size of E.coli bacterium," says Oeggerli. "The first time I photographed them I thought that they were missing from my specimen because they are so small. I didn't find a hole where they came out either, they were just lying around in these canyons."

fig. 03

ACANTHUS

Name of parent plant: Acanthus
Size: 72.6 micrometres.
This pollen is quite large, at more than 70 micrometres. "This is one of the first images I ever captured of a pollen grain," Oeggerli says. "You can see it has long, deep clefts in the sides, called *colpi*, which are hugely important. In summer the pollen loses moisture, and so it has these clefts to withstand volume changes without breaking. Sometimes my treatment removes these fissures, and this can be seen in the pollen in fig. 05."

fig. 04

VIBURNUM

Name of parent plant: Snowball plant
Size: 17.5-26.3 micrometres.
This snowball plant pollen tube snakes out from among the germinating pollen grains surrounding it. A pollen must move through a variety of floral tissues to access the ovules within the plant's pistil. "There are also other pollen pictured, and often there are chemical and biological barriers," Oeggerli explains. "The plant doesn't want to be fertilised by a different plant's pollen, because then it would lose its ovule."

fig. 05

VARIOUS

Name of parent plant: *Clockwise from top left*: treasure flower (*Gazania*), sea pink pollen (*Armeria*), pumpkin (*Cucurbita*), bromelia (*Wittrockia*), bamboo (*Fargesia*), acanthus (*Eranthemum*).
Sizes: 30.5, 59.5, 122, 42, 37, 70.3 micrometres.
Unmagnified, the specimens would all differ in size – the pumpkin has the largest pollen of any plant. "The surface is so strong, the pollen tube cannot grow through it," Oeggerli says. "They have pre-formed apertures, which differ from plant to plant."

fig. 06

SALIX

Name of parent plant: Purple willow
Size: 17.6 micrometres.
The yellow head is the pollen, and is stuck to the male part of the flower, which is shown red. The clefts in the pollen show that it's a dry specimen. "You can't see the pollen until you put the entire sample under the microscope," Oeggerli says. "It's impossible to arrange or move something so small, so I look for a frame by rotating and tilting the microscope – like picking someone out of a crowd for a photo." ■

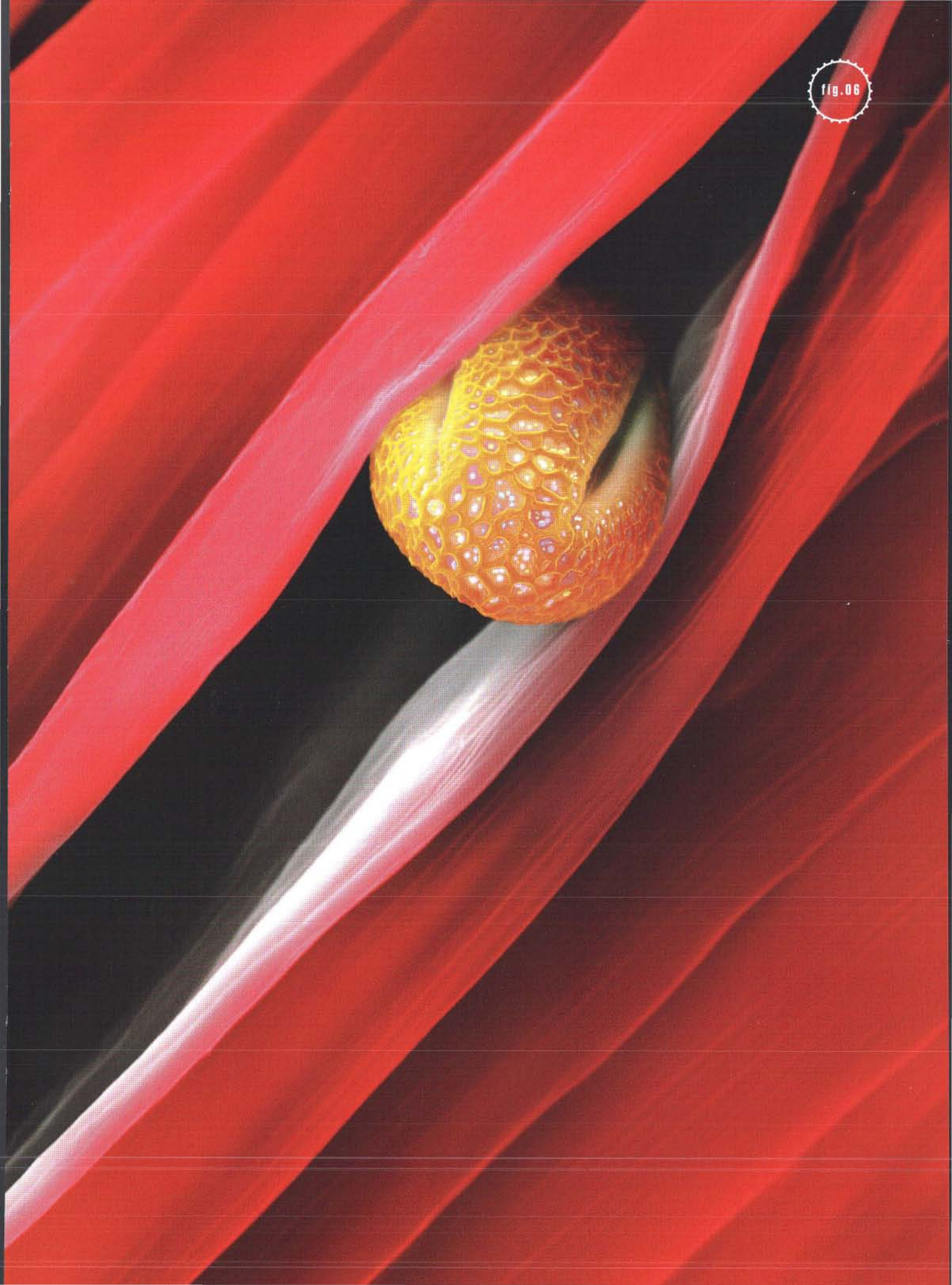


fig.06

UNDER

BY JONAH LEHRER

PRESSURE

STRESS DOESN'T KILL US –

BUT IT MAKES EVERYTHING

THAT DOES KILL US MUCH WORSE.

INSIDE THE SEARCH FOR A CURE

aboons are nasty and brutish. They have a long muzzle and fangs designed to inflict deadly injury, and are largely defined by their social habits – they live in groupings of several dozen and have a strict hierarchy. Whereas female rank is hereditary, males compete for dominance. These fights are bloody and the stakes are immense: a higher rank means more sex. The losers face a bleak array of options – submission, exile or death.

In 1978, Robert Sapolsky was a college graduate with a degree in biological anthropology and a job in Kenya. He set off for a year of fieldwork among baboons before returning to the US for grad school and lab drudgery. His wilderness experience consisted of backpacking trips; he had lit a campfire only once. On making his way to the bush, he discovered a sprawling savannah filled with zebras and wildebeests and elephants. "I couldn't believe my eyes," Sapolsky remembers. "There was an animal behind every tree. I was inside the diorama."

Sapolsky slowly introduced himself to a troop of baboons, letting them adjust to his presence. After a few weeks, he began recognising individual animals, giving them nicknames from the Old Testament. It was an act of rebellion against his childhood Hebrew-school teachers, who rejected the blasphemy of Darwinian evolution. "I couldn't wait to record that Nebuchadnezzar and Naomi were off screwing in the bushes," Sapolsky wrote in *A Primate's Memoir*. "It felt like a pleasing revenge."

Before long, Sapolsky's romantic vision collided with the dismal reality of living in the bush. His feet itched from a fungal infection, his skin was covered in insect bites, the Masai stole his stuff, he had awful diarrhoea, and he was terribly lonely. Sapolsky's subjects gave him no glimpse of good fellowship. They seemed to devote all of their leisure time – and baboon life is just that – to mischief and malevolence. "I discovered that I didn't like them very much," he says. "They're awful to one another, scheming and backstabbing. They're like chimps without the self-control." Although Sapolsky was disturbed – this was nature, red in tooth and claw – he realised that their cruelty presented an opportunity to investigate the effects of social upheaval. He noticed that the males at the bottom of the hierarchy were thinner and more skittish. "They just didn't look very healthy," Sapolsky says. "That's when I began thinking about how damn stressful it must be to have no status. You never know when you're going to get beaten up. You never get laid. You have to work a lot harder for food."

So Sapolsky set out to test the hypothesis that the stress involved in being at the bottom of the baboon hierarchy led to health problems. At the time, stress was mostly ignored as a medical subject. It was seen as an unpleasant mental state with few long-term consequences. "Studies had linked stress to ulcers, but that was about it," he says. "It struck most doctors as unlikely that your feelings could affect your health. Viruses, sure. Carcinogens, absolutely. But stress? No way." Sapolsky, however, was determined to get some data. He wasn't yet focused on human beings or public health. His transformation into one of the leading researchers on the science of stress would come later. Instead, he was busy learning how to shoot baboons with anaesthetic darts and then, while they were plunged into sleep, quickly measure their immune-system function and the levels of stress hormones and cholesterol in their blood.

In the decades since, Sapolsky's speculation has become scientific fact. Chronic stress, it turns out, is an extremely dangerous condition. And not just for baboons: people are as vulnerable to its effects as those low-ranking male apes. Although stress doesn't cause any single disease – in fact, the causal link between stress and ulcers has been largely disproved – it makes most diseases significantly worse. The list of ailments connected to stress is staggeringly diverse and includes everything from the common cold and lower-back pain to Alzheimer's disease, major depressive disorders and heart attack. Stress hollows out our bones and atrophies our muscles. It triggers adult-onset diabetes and is a leading cause of male impotence. In fact, numerous studies of human longevity in developed countries have found that psychosocial factors such as stress are the single most important variable in determining the length of a life. It's not that genes and risk factors like smoking don't matter. It's that our levels of stress matter more. Furthermore,

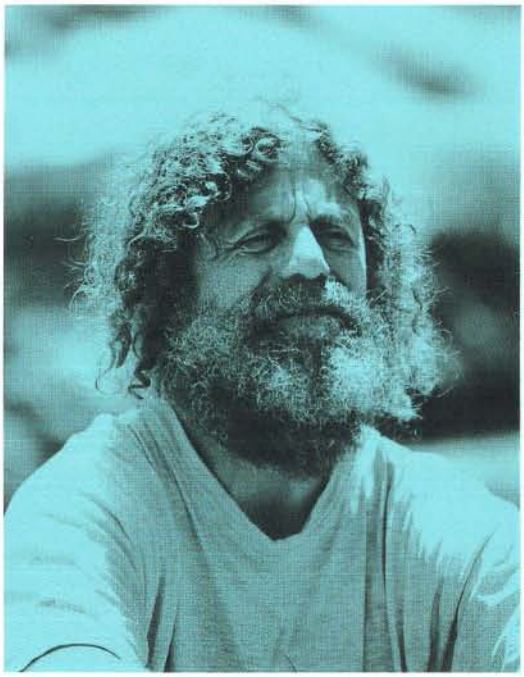
PHOTOGRAPHY: ELINOR CARUCCI; NATIONAL GEOGRAPHIC TELEVISION

IF STRESS IS AS BAD AS WE THINK, THEN WE NEED TO STOP TREATING THE SIDE EFFECTS AND **GO AFTER STRESS ITSELF**

the effects of chronic stress directly counteract improvements in medical care and public health. Antibiotics, for instance, are far less effective when our immune system is suppressed by stress; that fancy heart surgery will work only if the patient can learn to shed stress. As Sapolsky notes, "You can give a guy a drug-coated stent, but if you don't fix the stress problem, it won't really matter. For so many conditions, stress is the major long-term risk factor. Everything else is a short-term fix."

The emergence of stress as a major risk factor is testament to scientific progress: the deadliest diseases of the 21st century are those in which damage accumulates over time. (Sapolsky refers to this as the "luxury of slowly falling apart".) Unfortunately, this damage is exacerbated by stress. Although medicine has made astonishing progress in treating the fleshy machine, it is only beginning to grapple with those misfortunes of the mind that undo our treatments. The power of this view – that health is linked to our emotional state – connects with a range of observations, from the sociological to the molecular. On one hand, stress can be described as a by-product of a society that leaves people in a state of unease. But that feeling can now be measured in blood and urine, quantified in terms of glucocorticoids and adrenal hormones. And we are starting to see, with scary precision, the devastating cascade unleashed by these chemicals. The end result is that stress is finally being recognised as a critical risk factor, predicting an ever larger percentage of health outcomes.

To Sapolsky, the next step was obvious: attack the condition head-on. In 2003, he proposed a vaccine-like treatment that protects people against stress. It's an ambitious attempt to combat a societal scourge at the level of our DNA. Although years of work remain, Sapolsky now insists that, given the public-health consequences, it's time to take the problem seriously, to move our treatments beyond talk therapy and Valium. "Sometimes it's not enough just to tell people, 'You should really learn to relax,'" Sapolsky says. "If stress is as half as bad as we think it is, then we need to stop treating the side effects and go after stress itself."



Robert Sapolsky, based at Stanford University, is working on a vaccine-like treatment for stress

After his trip in 1978, Sapolsky began spending every summer in Kenya. In the early 80s, he happened upon a rare event: the highest-ranking female and a low-ranking one gave birth to daughters just days apart, and these newcomers allowed him to compare the effects of status on development. The first thing he noticed was that the high-ranking daughter hit every developmental landmark faster. She walked first, ate solid food earlier and interacted more with other baboons. The lesson, Sapolsky says, is that "status comes with privileges", which are present from birth.

Sapolsky describes a poignant scene that took place when the newborns encountered each other for the first time. "They can barely get around, but they're both so excited to see another baby," he says. "And so the low-ranking kid goes wobbling over to say 'hi'. But then, just as she gets near, the low-ranking mom grabs her daughter and drags her back. The poor kid has no idea what's happened, but she's just received her first lesson in the social hierarchy. The high-ranking kid is not somebody she can play with." For Sapolsky, the tragedy of such interactions is their lasting legacy. "I can come back 25 years later, when these kids are old matriarchs, and they'll be acting out the same dynamic. When they meet, the low-ranking baboon will just stare at the ground. That's what her mom was trying to teach her. She was being taught how to live with low rank. She was learning how to cope."

That coping comes with a steep cost. In a controlled lab experiment led by Jay Kaplan at Wake Forest University School of Medicine in North Carolina, a study involved macaques, small primates who, like baboons, live in a rigid social hierarchy. The scientists quickly discovered that macaques of high rank were less likely to develop heart disease, despite the fact that all of the animals were fed a diet high in saturated fat and cholesterol.

They also conducted experiments in which monkeys were put into a new enclosure, a move that forced them to struggle to maintain their status. This led to increased heart rate and blood pressure. (In fact, Kaplan saw a rise in arterial plaque even when the stressed monkeys were fed a low-fat diet.) The effect was more pronounced for females. Normally, male primates are twice as likely to suffer from heart disease. This difference between the sexes disappears, however, when females lose their rank. A similarly destructive process is at work in humans. Doctors speculated that increasing rates of cardiovascular disease in

women might be linked to the rising number employed outside the home, but that correlation turned out to be nonexistent. There were, however, two glaring exceptions to the rule: women were more likely to develop heart disease if they performed menial clerical work or when they had an unsupportive boss. The work wasn't the problem. It was the subordination.

One of the most tragic aspects of the stress response is the way it gets hard-wired at a young age – an early setback can permanently alter the way we deal with future stressors. The biological logic of this system is impeccable: if the world is a rough and scary place, then the brain assumes it should invest more in our stress machinery, which will make us extremely wary and alert. There's also a positive feedback loop at work, so that chronic stress actually makes us more sensitive to the effects of stress.

The physiology underlying this response has been revealed in the laboratory. When rats are stressed repeatedly, the amygdala – an almond-shaped nub in the centre of the brain – enlarges dramatically. (This swelling comes at the expense of the hippocampus, which is crucial for learning and memory and shrinks under severe stress.) The main job of the amygdala is to perceive danger and help to generate the stress response; it's the brain area turned on by dark alleys and Hitchcock movies. Unfortunately, a swollen amygdala means that we're more likely to notice potential threats in the first place, which means we spend more time in a state of anxiety. (This helps to explain why a more active amygdala is closely correlated with atherosclerosis.) The end result is that we become more vulnerable to the very thing that's killing us.

This acute sensitivity also makes us more vulnerable to stress-related diseases. Just ask Michael Marmot, a professor of epidemiology and public health at University College London. For the past 25 years, he's been running the Whitehall study, an exhaustive longitudinal survey launched in 1967 that has tracked some 28,000 men and women working in London. What makes the study so compelling is its uniformity. Every subject is a civil servant, a cog in the vast governmental bureaucracy. They all have access to the same healthcare system, don't (generally) have to worry about getting laid off and spend most of their workdays shuffling papers.

The British civil service comes with one other feature that makes it ideal for studying stress: it's hierarchical, with a precise classification scheme for employees. At the bottom are messengers, porters and security guards. Just above them are the clerical officers, followed by staff scientists and other professionals. This last group implements the policies dictated by powerful administrators who run the governmental agencies. Marmot wanted to investigate how differences in status "in people who are neither very poor nor very rich" might lead to measurable differences in health.

The differences are dramatic. After tracking thousands of civil servants for decades, Marmot was able to demonstrate that between the ages of 40 and 64, workers at the bottom of the hierarchy had a mortality rate four times higher than that of people at the top. Even after accounting for genetic risks and behaviours such as smoking and binge drinking, employees at the bottom still had nearly double the mortality rate of those at the top.

What, then, determines our health? Why were people in the lower ranks of Whitehall dying at a younger age? Marmot was forced to conclude that the significant majority of variation is caused by psychosocial factors, most notably stress. People of lower status in the Whitehall study experienced more negative stress, and this stress was deadly. (To take but one data point: fully two-thirds of an individual's risk of stroke was attributable to the person's socioeconomic status.) In fact, we're so sensitive to the effects of status that getting promoted from the lowest level in the civil service reduced the probability of heart disease by up to 13 percentage points. Climbing the social ladder makes us live longer.

However, the Whitehall results aren't a straightforward analysis of stress, at least not as it's usually defined. After all, people in leadership positions often describe their jobs as extremely stressful. They work longer hours and have more responsibilities than those at the bottom of the bureaucratic hierarchy. Consider the self-report of Nigel, a high-status administrator: "There were 2,000 people, and I was responsible for all the personnel aspects, contracts and all the common service... It had every sort of challenge that you could ever wish to meet. A very active job and a lot of stress, but a very enjoyable job – and you got a tremendous amount of satisfaction from doing a good job."

Notice the reference to stress; undoubtedly Nigel thought of himself as under lots of pressure. In contrast, here's the self-report of Marjorie, a typist: "I went to the pool and sat there typing documents. Which was absolutely soul-destroying... The fact that we could eat sweets and smoke was absolute heaven, but we were not allowed to talk." Researchers refer to the "demand-control" model of stress, in which the damage caused

REDUCE STRESS – WITH SCIENCE!

CONFRONT YOUR FEARS
When paratroopers are first learning to parachute, they experience a massive stress response. In fact, one study on a group of Norwegian airmen found that this response started a long while before the jump and lasted for hours afterwards. But something interesting happened when the soldiers kept jumping out of planes. Instead of being stressed for hours at a time, they showed elevated levels of stress hormone only while in midair, which is precisely when they needed it. The chronic stress response that causes long-term harm had all but disappeared.

ILLUSTRATIONS: ICONWERK

MAKE FRIENDS
Social relationships are a powerful buffer against stress. In fact, several studies in Europe and the US have found that people with fewer friends and family members around them to call upon and depend on have significantly shorter life expectancies. (The magnitude of the effect is roughly equivalent to smoking cigarettes.) One likely explanation for this phenomenon is the stress of loneliness. Studies of monkeys have found that more socially isolated animals have higher levels of stress hormones, a reduced immune response and a higher mortality rate.

DRINK IN MODERATION
Alcohol is an anxiolytic – it melts away anxieties by dampening the response of the sympathetic nervous system and reducing the release of stress hormones. That's why a beer tastes so good after a long day. But don't get carried away: whereas the moderate consumption of alcohol might reduce the stress response, blood alcohol levels above 0.1 per cent – the UK has a 80mg/100ml limit for driving – trigger a large release of stress hormones. Although you might feel drunkenly relaxed, your body is convinced that it's actually in a state of mortal danger.

GET ENOUGH SLEEP AT NIGHT
Sleep deprivation is not just about feeling tired. Recent studies have found that even a single night of insufficient sleep – whether it's spent working the night shift or playing *World of Warcraft* – triggers an automatic spike in stress hormones. And here's where biology gets cruel: this response then makes it harder to fall asleep when you want to, since your sympathetic nervous system is revving at a higher rate. The result is more stress and more insomnia, which helps to explain why sleep problems are such an important risk factor for depression.

DON'T FIGHT
While observing baboons, Stanford biologist Robert Sapolsky found there was a set of personality traits linked reliably with lower levels of stress hormones. One of these was the ability to walk away from provocations that might send a normal baboon into a snarling hissy fit. Interestingly, this less aggressive personality turned out to be exceedingly effective: the nice baboons remained near the top of the troop hierarchy about three times longer than the baboons who were easily provoked into a fight. They also had a lot more sex, which is a great stress reliever.

MEDITATE
Numerous studies have demonstrated that even a short training session in meditation can dramatically reduce levels of stress and anxiety. In fact, a recent study led by Sian Beilock, a psychologist at the University of Chicago, demonstrated that a ten-minute lesson in mindless meditation seemed to reduce stress in those taking a high-stakes maths exam, leading to a five-point increase on average. She argues that meditation allows people to do a better job of not fixating on negative and stressful thoughts, thus freeing up brain space to focus on the arithmetic.

DON'T FORCE YOURSELF TO EXERCISE
Although exercise is remarkably effective at blunting the stress response, at least for a few hours, this effect exists only if you want to exercise in the first place. After all, a big reason working out relieves stress is that it elevates your mood; when mice are forced to run in the lab, their levels of stress hormones spike. So when you force yourself to go to the gym and then suffer through 30 minutes on the treadmill (lamenting the experience the entire time), you don't reduce your stress levels. In fact, you might be making things worse.

by chronic stress depends not just on the demands of the job but on the extent which we can control our response. "If an employee has a high degree of control over work, it is less stressful and will have less impact," Marmot writes. (This helps to explain why the women with the meanest bosses showed the highest incidence of heart disease.)

The moral is that the most dangerous kinds of stress don't feel that harmful. It's not the late night at the office that's going to kill us; it's the feeling that nothing can be done about any current stressful situation. The person most at risk of heart disease isn't the high-powered executive anxious about their to-do list – it's the frustrated office cleaner stuck suffering from existential despair.

Stress is a chemical problem. When it occurs, a tiny circuit in the brain triggers the release of glucocorticoids, a family of stress hormones that puts the body in a heightened state of alert. The molecules are named after their ability to increase glucose levels in the blood, thus providing muscles with a burst of energy. They also shut down all non-essential bodily processes, such as digestion and the immune response. "This is just the body being efficient," Sapolsky says. "When you're being chased by a lion, you don't want to waste resources on the small intestine. You'll ovulate some other time. You need every ounce of energy just to get away." But glucocorticoids have a nasty side effect: when they linger in the bloodstream, as they might due to chronic stress, damage accumulates. It's the physiological version of a government devoting too many resources to its defence department, Sapolsky says. The body is so worried about war that it doesn't fix the roads or invest in schools.

Interestingly, the effects of stress appear particularly toxic to the brain. Elizabeth Gould, a neuroscientist at Princeton, is best known for demonstrating that the birth of new neurons – a process known as neurogenesis – takes place in the adult brain. For the

past several years, Gould has been studying the relationship between neurogenesis and stress in primates. She has found that when stress becomes chronic, neurons simply stop investing in themselves. Neurogenesis slows and dendrites (the branches of a neuron) shrink. Neuronal arbors then retreat. In fact, the very act of keeping primates in standard lab enclosures – often just bare wire cages – is so stressful that for years scientists had a warped understanding of the primate brain. Gould has become an ardent advocate of "enriched enclosures", which provide the animals with things to play with and social interaction.

These cellular alterations help to explain why, as researchers noted in a recent review article, a "large part of the changes in brain structure and function (induced by chronic stress) have similar characteristics to those observed in neurodegenerative diseases, most notably Alzheimer's." And the higher the level of stress hormone, then the greater the level of cognitive decline.

One of the most disturbing aspects of these effects is the way they're transmitted across generations. Gould has demonstrated, for instance, that if a pregnant rhesus monkey is forced to endure stressful conditions, like being startled by a horn, her offspring are born with reduced neurogenesis, even if they never actually experience stress after birth. This prenatal trauma, like any other endured in infancy, has lifelong implications. The offspring of monkeys stressed during pregnancy have smaller hippocampi, and suffer from elevated levels of stress hormone and anxiety. Look at humans – a recent study found that children abused in childhood by parents showed epigenetic changes to their DNA, which altered how their genes were read. The most prominent changes involved genes encoding glucocorticoid receptors, which led to a magnified stress response. So although the abuse might be temporary, the damage inflicted is permanent – a wound that never heals.

Not every bout of stress is so devastating. As the Whitehall data demonstrates, the executives in the corner office reported high levels of stress and yet seem to survive just fine. Other experiments show that intense exercise – such as running for hours on a treadmill in a gym – can lead to the release of glucocorticoids. And yet physical exercise is reliably associated with all sorts of positive effects.

These anomalies have led scientists, including Gould, to search for additional molecules in the brain that might serve as buffers for the stress response. Gould's short list of candidates focuses on neuromodulators such as dopamine and oxytocin that are released when we experience pleasure. She argues that these feelings of enjoyment – the ability to find meaning in our work, even if it's stressful work – may counteract the effects of glucocorticoids. These molecules might also explain why not every cleaner dies of heart disease at a young age and why enjoyable forms of exercise are good for us. "There are important individual differences in how people respond to stress," Gould says. "Soldiers experience lots of stress in war, but most of them won't get post-traumatic stress disorder. What accounts for those differences? And how can we help the most vulnerable?"

obert Sapolsky looks out of place on the Stanford campus. He's surrounded by manicured lawns and preppy students, but his appearance is deliberately untamed. His face is hidden by a bushy beard, which extends below his neck in the style of late Darwin. All that remains visible are pale blue eyes and the Sun-worn wrinkles that tell you he's smiling.

In recent years, it has been harder for him to study primates in the wild. The main problem is the intrusion of humans. "The original beauty of studying stress in baboons was that they didn't act like people," Sapolsky says. "The animals don't smoke, they don't lie on questionnaires and they all eat the same basic diet." Unfortunately, the increasing sprawl of human settlements means the baboons now supplement their natural menu of fruit, seeds and small antelopes with human trash. As a result, it has become all but impossible to disentangle the negative effects of stress from the negative effects of bad diet.

The difficulty of conducting research has led Sapolsky to focus on lab work. The theme remains the same – he is single-minded about stress – but the tools are different. Instead of tranquilising baboons, he oversees a molecular-biology lab, its shelves and counters cluttered with fridges, notebooks and salt solutions. "It kills me that I can't spend more

time in Africa," he says. "But you take what you can get. And right now, it's this lab."

This doesn't mean Sapolsky has stopped thinking big. His main project is absurdly ambitious: he wants to create a vaccine-like treatment for stress, a genetic therapy that can prevent struggle from wrecking brain and body. He started thinking about the treatment in 1992, during the early days of gene therapy. At the time, it seemed simple: if the chronic drip of glucocorticoids is toxic, then why couldn't these chemicals be stopped before it's too late?

That straightforward goal concealed a series of technical challenges. The first was that Sapolsky couldn't just eliminate glucocorticoids from the bloodstream, because they are involved in all sorts of important functions, such as helping you run for your life. Second, Sapolsky needed to get his treatment past the blood-brain barrier – the specialised capillaries that prevent blood contaminants from entering the brain. Sapolsky's vaccine-like cocktail needed to deliver a potent mixture of genes to the cortex – these genes would counteract the stress response – but the most common mechanisms of delivery, such as free-floating strands of DNA called plasmids, were denied entry. There were a few years of false starts, but Sapolsky and his post-docs continued to play around with the herpes simplex virus, which has been used as a viral vector in gene therapy research for decades. Herpes was a good candidate because it slips easily into brain cells. Sapolsky set about deleting all the dangerous genes in the virus, replacing each of them with an assortment of "neuroprotective" ones, which increase the production of growth factors, antioxidants and substances that mimic oestrogen (it counters many of the deleterious effects of stress on the brain). Brain cells infected by the virus would then be protected rather than get subjected to stress.

THERE ARE VERY IMPORTANT INDIVIDUAL DIFFERENCES WHEN LOOKING AT HOW PEOPLE RESPOND TO STRESS FACTORS

The question was how to get the herpes to turn on at key moments. Fortunately, natural selection solved the problem. "Viruses aren't dumb," he says. "They don't want to become active until we're vulnerable and our immune response is suppressed." How does the virus know we're stressed? To Sapolsky's pleasant surprise, the virus already had the necessary genetic machinery: it automatically monitors glucocorticoids in the bloodstream. It had evolved to start expressing its genes whenever its host felt overburdened by the world.

After several years of genetic engineering – it's not easy to substitute all the dangerous genes with their therapeutic replacements – Sapolsky began introducing the modified herpes virus into rodent brains. Then he induced a series of tragedies, such as a massive stroke or an extended seizure, which would trigger the release of glucocorticoids (chronic stress is like a slow-motion stroke). Within minutes, the virus began pumping out neuroprotective proteins, which limited the extent of cell death. As a result, the damage was contained. For instance, rats given the herpes treatment were able to stave off practically all cell loss, while control rats lost nearly 40 per cent of neurons in a given region. In the hippocampus, neuronal death was reduced substantially. "To be honest, I'm still amazed that it works," he says. "It's not going to help anybody soon" – the research is still years away from clinical trials – "but we've proved that it's possible. We can reduce the neural damage caused by stress."

The power of Sapolsky's vaccine is that it can rescue us from ourselves, in theory. Like those baboons in the bush, we live in a stratified society that comes with costs, which make us depressed, give us back pain, shrink the brain, clog the arteries and weaken the immune system. They shorten our already short lives.

The science of stress illuminates the damage. It documents the chemistry that unravels us from the inside. One day, it might give us options for preventing the damage, silencing the stress response at its source. But these are mere fancy fixes for what remains a societal problem. We tell our kids that life isn't fair, but we fail to mention that the unfairness can be crippling, that many of us will die because of where we were born. This is the cruel trick of stress: if it were only a feeling, if there were only the despair of having no control or the anxiety of doing without, then stress would be bad enough. But the feeling is just the trigger. We are the loaded gun. W

Jonah Lehrer is a contributing editor at WIRED *US. He wrote about Pixar in our 07.10 issue*

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test

SMARTPHONES / HIGH-PRESSURE JET-WASHERS / SEA SCOOTERS

EDITED BY CHRIS FINNAMORE

PHOTOGRAPHY: DAVE LIDWELL

Kings of the sea

WIRED gets propelled with the latest electric water scooters - p144

Touchscreen intelligence

They may have brains and beauty – but do the latest smartphones pass our tests?

DELL STREAK

We think it's a phone. Dell thinks it's a tablet. In terms of size, it's between the two at 15.3 x 10 x 7.9cm. Either way, the Streak makes calls and has a large screen for surfing.

It runs Android 1.6 (now about a year old) but it runs very smoothly. The web browser supports pinch-to-zoom but, oddly, Google Maps doesn't. The camera is excellent.

The downside is Exchange server support – as with the Xperia, Google and Exchange data are kept separate, and you get only a 30-day trial of the Exchange sync software.

WIRED Fast; great screen

TIRED Exchange sync fees

●●●●●●●●●●

Free on £25-per-month data-only contract dell.co.uk

PALM PIXI PLUS

In a marketplace dominated by big slabs, the Pixi is refreshingly compact. Its qwerty thumb-pad seems cramped at first, but once you're used to typing with your fingernails you can text and email at speed.

It runs Palm's webOS software, and its main strength is multitasking. There are no Twitter or Facebook apps built in, but Palm's App Catalog has some free ones. The OS isn't as smooth as the Android phones', and our test video file stuttered.

WIRED Quick thumb-typing
TIRED Software can be slow

●●●○○○○○○○

Free on £25-per-month contract
palm.com/uk

SONY ERICSSON XPERIA X10

The X10 has the same Android 1.6 operating system as Dell's Streak, but it doesn't run as smoothly. It has a sharp, colourful, hi-res (480 x 854-pixel) screen, and the interface uses pretty 3D icons and some fancy transparency effects.

Annoyingly, Exchange and Google sync use separate, non-communicating apps. Twitter and Facebook updates head to the *Timescape* app, which displays them as a stack of opaque tiles – attractive, but slow.

WIRED Appealing interface
TIRED Sluggish overall performance

●●●●○○○○○○

Free on £35-a-month contract
sonyericsson.com

MOTOROLA FLIPOUT

The FLIPOUT is fun, compact and quirky – its touchscreen rotates sideways and up to reveal a qwerty thumb-pad. The phone runs Android 2.1 smoothly and it helpfully pulls Exchange and Google email, calendars and contacts into one place.

The screen is smaller and has lower resolution than most Android phones, but there are seven home screens and you can resize the widgets. The low pixel-count does cut down on the number of compatible apps in the Android Market, though.

WIRED Cute design; speedy
TIRED Low-res screen; limited apps

●●●●●●●●●○

£TBC motorola.com

VERSACE UNIQUE

This "luxury" phone aims to bring smartphone features to a sector more used to basic-but-expensive handsets. Its case is hand-polished stainless steel, the rear is calfskin and the touchscreen is made from 59.5 carats of sapphire crystal.

The Unique supports corporate Exchange email, but you can't sync with Google or Exchange contacts or calendars. The web browser also takes an age to render non-mobile websites. Still – you do get a great big Versace logo on the back.

WIRED Slick interface
TIRED Key features missing; er, cost

●●●●●○○○○○

£4,800 www.versace.com/mobile

HOW WE TESTED

We set up each phone to sync contacts, calendar and email with both Google and Exchange servers. We visited websites with each handset's browser, checked if the phones could play an iPod Touch-format video and took test shots with the cameras. To measure battery life we played an MP3 file on repeat.

SMART STATS

	DELL STREAK	PALM PIXI PLUS	SONY XPERIA X10	MOTOROLA FLIPOUT	VERSACE UNIQUE
Operating system	Android 1.6	webOS 1.4.1.3	Android 1.6	Android 2.1	Proprietary
Display	5" 800 x 480 pixel	2.4" 320 x 400 pixel	4" 480 x 854 pixel	2.8" 320 x 240 pixel	3" 480 x 800 pixel
Storage	2GB plus 16GB MicroSD card	8GB	1GB plus 8GB MicroSD card	2GB plus 8GB MicroSD card	2GB plus 8GB MicroSD card
Camera	5 megapixel, LED flash	3 megapixel, LED flash	8.1 megapixel, LED flash	3 megapixel	5 megapixel, LED flash
Size/weight	153 x 10 x 79mm /220g	56 x 11 x 112mm /94g	117 x 11 x 119mm /135g	67 x 17 x 67mm /120g	55 x 16 x 105mm /165g
Applications	61,527 (androlib.com)	1,316 (Palm)	61,527 (androlib.com)	Not disclosed	None

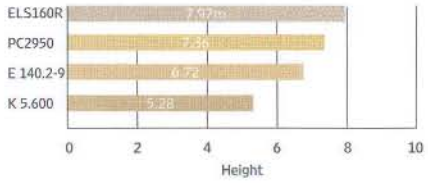
TEST

PHOTOGRAPHY: DAVE LIDWELL

Master-blasters for your patio

Give your outdoor entertainment space a scrub-up with a high-pressure water jet

HOW HIGH OUR TENNIS BALL FLEW



PHOTOGRAPHY: ROGER STILLMAN

SEALEY PC2950

Sealey's pressure washer comes pre-assembled, and has hooks to keep the mains cable and power hose tidy. The spray gun doesn't clip into the base unit, making storage a bit haphazard. You have to plug in a dedicated gun to spray detergent.

The PC2950 comes with a special "Rotablast" nozzle. This is meant to give the equivalent of 22MPa pressure, but we found the normal nozzle more effective. Its adjustable spray gun goes from a wide beam to a thin water-lance which easily sliced through our congealed muck.

WIRED Powerful, focused jet
TIRED Messy accessory storage

£317 www.sealey.co.uk

KÄRCHER K 5.600 + T200 PATIO CLEANER

The 5.600 is fiddly to put together. You have to attach the wheels, hose and pipe holder – we needed to trim the detergent control's pipes to make them fit. There's a clip for the spray gun, but the hose's thickness makes it hard to stow away neatly.

The spray width is adjusted by twisting the barrel; the "mix" setting brings detergent into the spray. However, its low water pressure had trouble shifting lichen. Our model came with an optional patio brush, which boosted performance.

WIRED Integrated detergent
TIRED Fiddly set-up; low pressure

£300 karcher.de/uk

NILFISK E 140.2-9 S X-TRA

The E 140.2-9 is the cheapest washer on test, but feels well made and packs away into a neat little unit. You have to plug in a dedicated attachment for adding detergent.

Rather than swapping the entire spray-gun barrel to switch from high-pressure jet to an adjustable spray, you need only change the nozzle. However, neither the high-pressure nor adjustable sprays had sufficient power or focus to shift our stubborn dirt – you'll need the optional £30 patio-cleaner accessory to get tougher jobs done.

WIRED Well-designed; inexpensive
TIRED Needs the optional extras

£230 nilfisk-alto.co.uk

FEEL THE PRESSURE

	SEALEY PC2950	KÄRCHER K 5.600	NILFISK E 140.2-9 S X-TRA	CLARKE ELS160R
Pressure	13MPa	12.3MPa	14MPa	15MPa
Flow rate	6.3 l/min	7.5 l/min	8.3 l/min	8.6 l/min
Dimensions	324 x 380 x 745mm	398 x 200 x 740mm	295 x 310 x 690mm	335 x 475 x 928mm
Weight	13kg	13.9kg	18.9kg	25.7kg

HOW WE TESTED

We enlisted the Test editor's family estate – which features a large patio covered in mould and lichen. We assessed how well each washer could remove the muck from a designated area using its various attachments and settings. To test pressure, we measured how far the washers could shoot a tennis ball in the air.

CLARKE ELS160R

Our tennis-ball test showed the huge ELS160R to be the most powerful washer here. The gun adjusts for power and water-jet width – push the nozzle in and out to adjust power, and rotate for spray type. It was the only model that didn't need its thinnest setting to penetrate our patio's dirt. It also has a handle-operated reel for the hose and two detergent tanks to feed soap into the water spray. Despite the washer's bulk and weight, it's easy to move around.

WIRED Huge power

TIRED Big and expensive

●●

£423 machinemart.co.uk

TEST

TEST

Why swim when you can scoot?

Speed through the deep blue sea (or your local lido) by adding some underwater propulsion

SEA-DOO SEASCOOTER EXPLORER X

The Explorer X is heavy, so although you can't feel the weight in the water, you'd want to drive it to the jetty. It feels tough, and you can remove the battery for easy charging.

There are three speeds, and it pulls strongly in top. It was only marginally quicker than the GTI in a straight sprint, but pulled away on our longer slalom route once it had a chance to accelerate to top speed. The GTI may be best for lightweight passengers, but the Explorer X has the grunt to haul heavy kit around.

WIRED Powerful; manoeuvrable

TIRED Heavy; expensive

●●●●●●●●●●

£900 www.seadooseascooter.com

SEA-DOO SEASCOOTER GTI

It's trickier to charge the GTI than the other scooters – you have to remove the nose-cone, then use the supplied air pump to pop off the inner seal to gain access to the battery. It's naturally buoyant, but you can add ballast by loading the nose-cone cavity with rocks.

It has only one speed, and although the GTI doesn't feel as powerful as the Explorer X its light weight made it almost as fast when pulling our swimming-trunk-clad testers. We'd value the Explorer X's power when dressed in full scuba gear and hauling air cylinders.

WIRED Light and fast
TIRED Tricky battery access

£400 www.seadooseascooter.com

SCUBAPRO SEAWING NOVA FINS

Instead of a single piece of moulded rubber, the Seawing Nova's Monprene boot and fin are separated by twin articulated joints. Scubapro claims this makes the fins more efficient; when you kick, the fin stays rigid and angles up at 45 degrees rather than bending in a curve. This pushes water straight backwards from the fin, efficiently driving the swimmer through the water.

The Novas are highly effective. Our swimmer was faster in all tests than with any of the scooters.

WIRED Comfortable; fast
TIRED Burning calves

£129 scubapro.com

BLADEFISH SEAJET 5000

The Bladefish's chief advantage is its compact size and relatively light weight – it's nearly a third of the weight of the Seadoo Explorer. It's also small enough to fit in a backpack or suitcase, so makes sense when walking to the beach or travelling by plane. Charging is simple – it plugs straight into the mains.

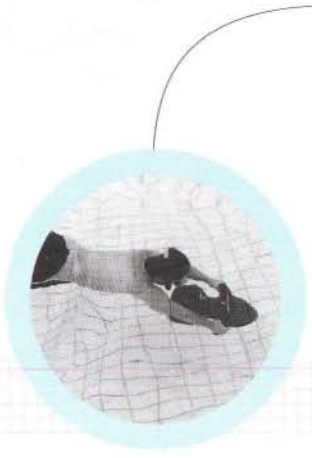
The Seajet has three speeds, but even in top feels sedate – we managed to beat it swimming barefoot. It's fine for relaxed cruising, but don't expect to make fast progress.

WIRED Compact, light and simple
TIRED Slow – you may as well swim

£600 bladefish.net

SCOOTING STATS

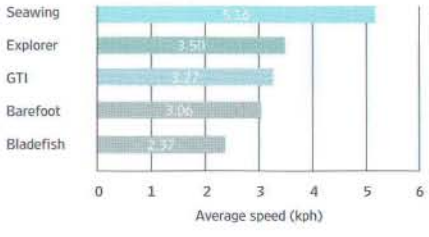
	SEA-DOO EXPLORER X	SEA-DOO SEASCOOTER GTI	SCUBAPRO SEAWING NOVA	BLADEFISH SEAJET 5000
Depth rating	40m	30m	N/A	50m
Battery run time	50 mins	45 mins	N/A	70 mins
Size	320 x 710 x 320mm	385 x 612 x 312mm	265 x 641 x 85mm	385 x 160 x 365mm
Weight	14.5kg	8.3kg	2.8kg	4.8kg



HOW WE TESTED

We took the sea scooters and fins to London Diving (londondiving.net). We checked outright performance with a 12m sprint, noting down the average of two runs, and tested a combination of outright speed and manoeuvrability with a four-length race and a slalom through hoops.

12M SPRINT SPEEDS



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THE 09.10 COLOPHON

THIS MONTH...

Welcome on board: Paul Rider, our new deputy art director.

International jealousy: the chef in the WIRED US canteen serves honey from his own beehives.

Chocolate greed: WIRED's managing editor returned from San Francisco with a jar of 90 TCHO-a-day chocolates, made by WIRED's founder Louis Rossetto (we wrote about them in issue 02.10). The data doesn't lie – WIRED is an office populated by chocolate-junkies.

Chocolates brought in to the WIRED office: Thursday July 1
Finished on: Wednesday July 7
Working/chocolate-eating days: five

TCHOs consumed per day (by 11 staff + three freelancers): 18
Average daily consumption: 1.2
Off the end of the bell curve – executive editor, Greg Williams: seven consumed in one day.

Most popular flavours, in order of consumption:
1. Chocolatey
2. Fruity
3. Nutty
4. Citrus

Enigma competition: congratulations to Tony Wu (*@tonytlwu* – pictured left, with his new iPad), our Enigma winner. Visit *wired.co.uk/enigmafarewell* for a list of notable citizens, entry highlights and, of course, the answers. Thanks to the hundreds of you who played, tweeted, teamed up and shared clues throughout the competition. Well done all.

Players: 290
Submitted answers/tweets: 2,461
Teams: 32
Average number of tweets per player: eight
Average completed challenges per player: seven

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Sources for the WIRED Index (page 52):
[1] Bowker, PubTrack Consumer Database **[2]** centennialbulb.org **[3]** *BMJ* 2008;337:a2825 **[4]** Dan Martin, executive VP, SEMI PV Group, 5/05/2009 **[5]** IBM, Information Management Facts **[6]** Morgan Stanley Internet Trends, 07/06/10 **[7]** Morgan Stanley Internet Trends, 07/06/10

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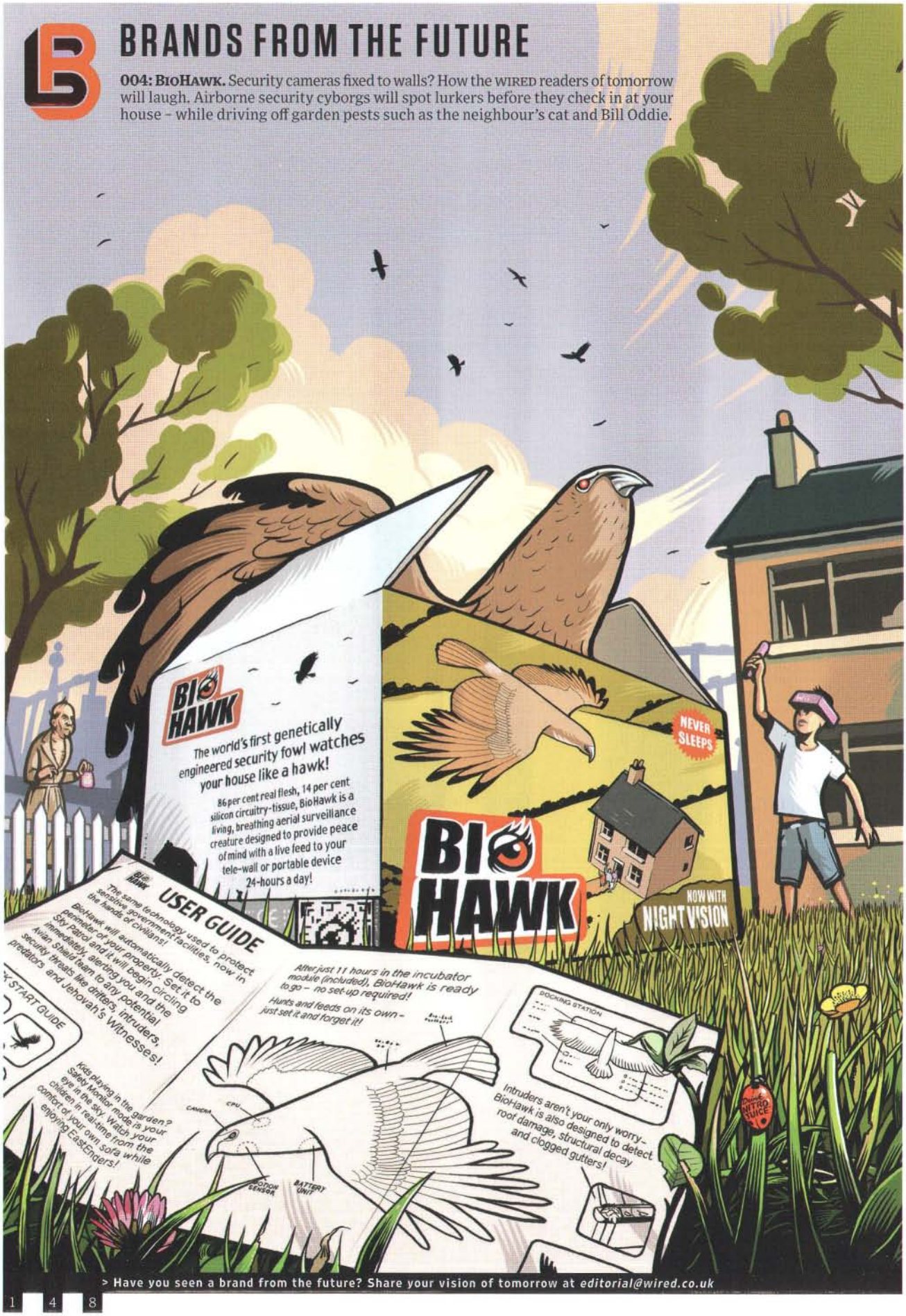
BRANDS FROM THE FUTURE

004: BioHawk. Security cameras fixed to walls? How the WIRED readers of tomorrow will laugh. Airborne security cyborgs will spot lurkers before they check in at your house – while driving off garden pests such as the neighbour's cat and Bill Oddie.



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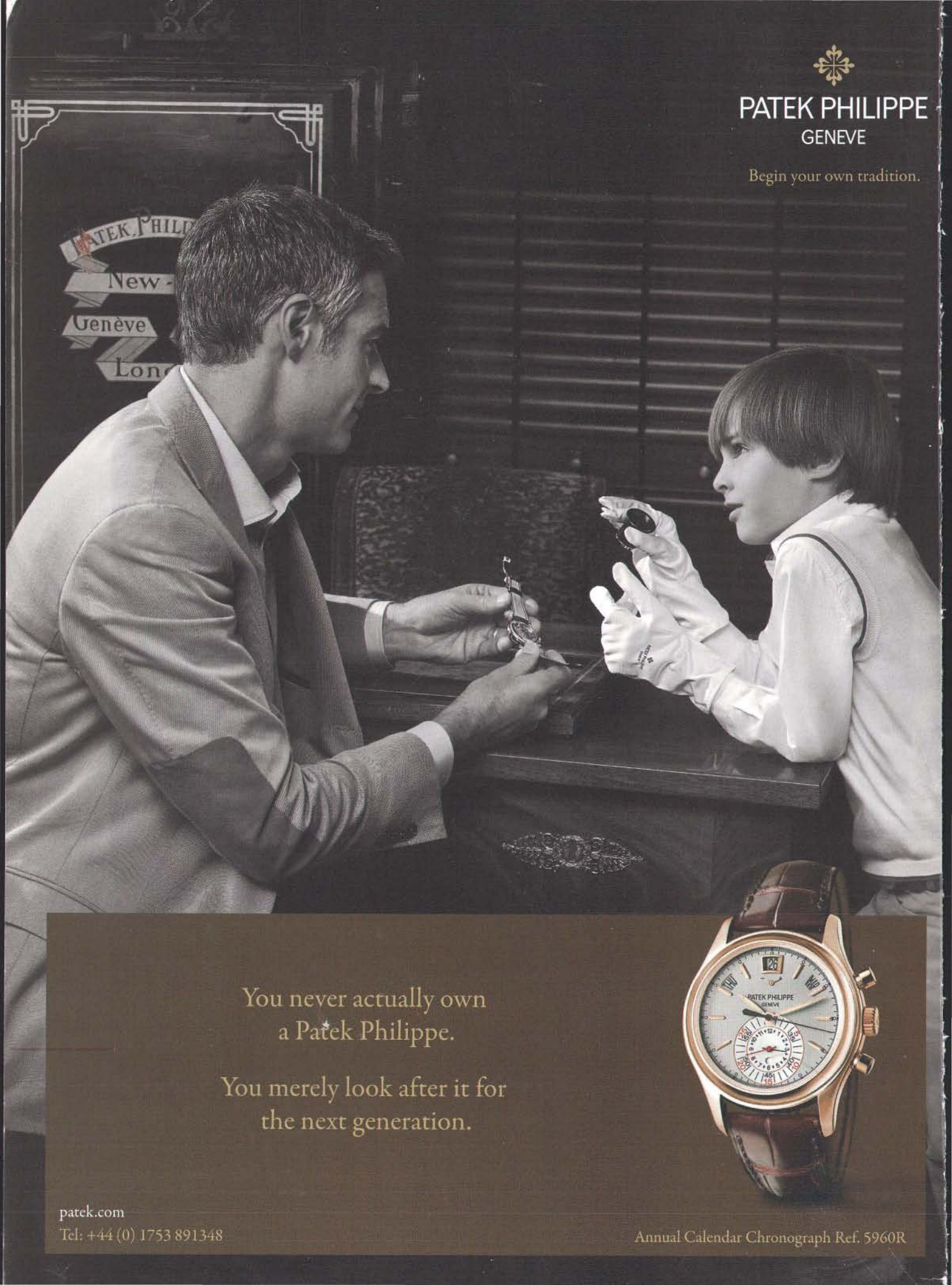
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